INSTRUCTION MANUAL
MODEL 200B
FREQUENCY COUNTER

SERIAL NO. _____

MODIFICATIONS _____

COMPUTER MEASUREMENTS CO.

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MODEL 200

FREQUENCY COUNTER

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SECTION I

INTRODUCTION

1-1 General Characteristics

The Computer Measurements Company Model 200 Frequency Counter is a high-speed, accurate electronic instrument which performs two functions with respect to electrical signal impulses fed into its input:

1. Measures automatically and directly the frequency of the input signal; or

2. Gives total or aggregate count of impulses arriving during any interval controlled by manual switching.

The input signals may be simple sine waves or have almost any complex periodic form such as square waves, triangular waves, distorted waves, containing large numbers of high-amplitude harmonics, periodic pulses, etc. With such periodic input signals the unknown frequency is measured directly by counting the exact number of impulses arriving during a precisely measured period of time.

Totalized count or average frequency of input signals of completely random nature, such as shot impulse noise, also may be determined; in this case, discrete pulses occurring as close together as 5 microseconds, approximately, still are resolved and recorded as separate counts.

The answer in all cases is given in digital form by means of an illuminated numeral in each of four columns on the front panel. These columns of display numbers are the integral front faces of plug-in Models 120C and 100C Decade Counting Units which do the actual counting within the instrument. The reading is direct, requiring no interpolation, mental arithmetic, or use of charts or graphs.

1-2 Other Uses of the Model 200

In addition to counting and measurement of frequency and period, the Model 200 is useful in measuring many other physical parameters. With appropriate transducers it is possible to measure such unknowns as speed, revolutions-per-minute, temperature, pressure, acceleration, strain, displacement, weight, fuel flow, etc. In fact, any mechanical, chemical, optical or other type variable which can be converted into electrical impulses can be measured with digital accuracy.

1-3 Specifications

Frequency Measurement

Frequency Range:	1 - 220,000 cycles per second 0 - 220,000 pulses per second
Accuracy:	± 1 count ± stability
Time Bases:	0.1 second, 1 second
Read-Out:	Four digits: One-tenth of cycles per second; Cycles per second; (Five digits optional)

Totalizing Count

Frequency Range:	1 - 220,000 cycles per second 0 - 220,000 pulses per second
Count Capacity:	10,000 counts (100,000 counts optional)

General

Input Sensitivity:	0.1 volt rms: 100 to 220 kc 0.05 volt rms: 10 - 100,000 cps 0.07 volt rms: 1 - 10 cps Positive pulses: 0 - 100,000 pps (0.2 volt or more per second rise characteristic) Negative pulses: Depends upon duty cycle
Input Impedance:	0.05 megohm and 50 mmf
**Stability:	± 0.1% (normal power line stability)
Display Time:	Automatic: Continuously variable 0.1 to 10 seconds Manual: Until reset
Power Requirements:	115/230 volts ± 10%, 50 - 60 cycles (50 - 400 cycles optional) 145 watts
Dimensions:	16" wide x 7 1/2" high x 12" deep
Weight:	26 lbs. net
Finish:	Panel: Light grey baked enamel Case: Dark grey baked enamel

1-4 Additional Features

Input Attenuator:	Adjusts sensitivity to accomodate input signals from 0.05 volts to 150 volts rms thus permitting optimum signal-to-noise ratio.
Self-checking:	Built-in test switch for check of proper operation by self-counting of internal time base. Also provides method of alignment of time base frequency dividers without use of auxiliary equipment.
Accessory Socket: **	Octal-type socket at rear of chassis provides power for auxiliary equipment: 6.3 v.a.c. @ 5 amp., +250 v.d.c. @ 24 ma. (unregulated), -150 v.d.c. @ 1 ma., (regulated) Standard frequency pulses of 10 cps from internal time base are available at this socket for use with external equipment. External standard frequencies from 0 to 100,000 cps also may be injected in lieu of internal time base signals.

** NOTE: For Model 200 instruments in which the optional XD-100A Crystal Time Base Plug-in Unit has been incorporated the time base stability and Accessory Socket facilities are modified as below:

Temperature-controlled Crystal Oscillator Time Base:	Plug-in precision accuracy which reduces errors to $\pm$0.0001% $\pm$1 count.
Accessory Socket:	6.3 v.a.c. @ 2.3 amp., $\pm$250 v.d.c. @ 24 ma. (unregulated), -150 v.d.c. @ 1 ma. (regulated) Standard frequency pulses of 100 kc, 10 kc, 1 kc, 100 cps and 10 cps from internal time base for use with external equipment.

SECTION II

OPERATION INSTRUCTIONS

2-1 Installation

The Model 200 has no special installation requirements. It should be operated in a reasonably well ventilated area with the bottom of the cabinet and cooling fan exhaust port unobstructed. Power requirements are nominally 117 volts, 50 - 60 cycles, 145 watts, but satisfactory operation will be obtained on line voltages from 105 to 130 volts.

To prevent possible spurious or false counting from line voltage transients in commercial areas it is recommended that the ground terminal at the rear of the cabinet be connected to a good external ground. The input connection to the Model 200 also must be fully shielded to prevent noise pick-up. The shielded cable furnished with the instrument or similar co-axial cable should be used for this purpose.

When auxiliary equipment such as magnetic pick-ups, photocell units, or other transducers are used, care should be taken to see the transducers themselves are fully shielded and a good ground connection made from the transducer cases to the shield of the Model 200 input co-axial cable or directly to the Model 200 chassis ground.

2-2 Self-Checking the Model 200

To put the instrument into operation, the power cord should be connected and the POWER switch turned on. All front panel controls are shown in Fig. 1.

Some random counting may occur during the first few seconds but after a warm-up period of about five minutes the instrument will be stabilized and proper operation can be checked through the built-in self-test feature as follows:

1. Set the TIME BASE switch to "ON".

2. Set the COUNT switch to "OFF".

*3. Rotate the DISPLAY knob near, but not quite, to its full counter-clockwise position for short display time and automatic operation.

4. Rotate the SENSITIVITY knob to its extreme counter-clockwise position marked "TEST".

5. Rotate the GATE TIME knob to its extreme counter-clockwise position of "0.1 SEC". The number displayed on the front panel by the Model 100C Decade Counting Units should now read "0006". These figures will be indicated by means of a lighted numeral in each column.

*Note: When the DISPLAY knob is rotated fully to its extreme counter-clockwise position marked MANUAL display time is infinite. For this condition, the automatic reset is disabled; any count displayed will be held indefinitely and the instrument must be reset manually by pressing the MANUAL RESET button.

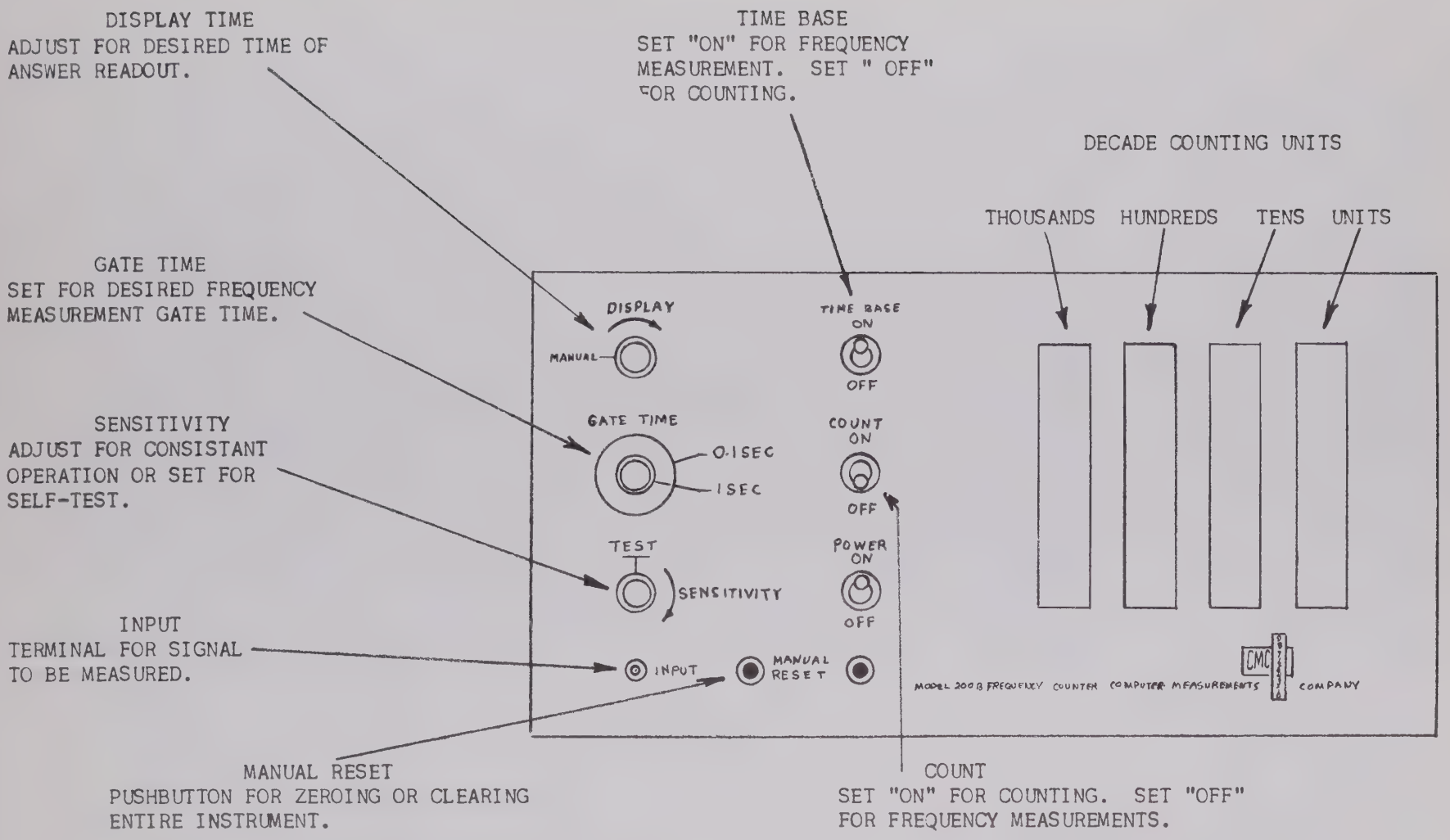


FIG. I

FRONT PANEL CONTROL FUNCTIONS

6. Rotate the GATE TIME knob clockwise to its other setting of "1 SEC". This position now should give a test reading of "0060".

Obtaining these test numbers of 0006 for the GATE TIME position of 0.1 SEC and 0060 for the 1-SEC position is assurance that the Model 200 is accurately calibrated and operating properly for all frequency and counting measurements.

NOTE: The above test numbers do not apply if a Model XD-100A Crystal Time Base plug-in unit has been added to a Model 200 Frequency Counter. Refer to Paragraph 7-5.

2-3 Frequency Measurement

The Model 200 measures frequency by counting the number of cycles, pulses or events, which arrive during a precisely measured period of time. The measured time may be 0.1 second or 1 second as selected by the GATE TIME switch knob position. After each counting period is over, the frequency is displayed in terms of cycles per 0.1 second, or cycles per second. The procedure for measuring frequency is as follows:

1. Connect source of frequency to be measured to INPUT connector.
2. Set the TIME BASE switch to "ON".
3. Set the COUNT switch to "OFF".
4. Turn the SENSITIVITY control completely clockwise.
5. Rotate the GATE TIME switch knob to counting interval desired (usually the 1 SEC. position).
6. Adjust the DISPLAY knob for desired answer display time.
7. Reduce the sensitivity by rotating the SENSITIVITY knob counter-clockwise to lowest position which still gives consistent counting.
8. The Model 200 now counts the input signal and displays the frequency measure in terms of "cycles per 0.1 second" or "cycles per second", depending upon the GATE TIME switch knob position.

When using the 1 SEC position of the GATE TIME switch frequencies from 1000 up to 9,999 can be read directly to four significant figures on the display of the Decade Counting Units across the front panel. With the same GATE TIME switch position, for frequencies below 1000 cps the number of available significant figures drops as the frequency is reduced; in which case the display columns of the Decade Counting Units, beginning at the left, begin to read "0" as they are no longer used.

The 0.1 SEC position of the GATE TIME switch is most useful when highest order of accuracy is not required but a rapid read-out is desirable. If

this 0.1 SEC position is used and the DISPLAY knob adjusted for minimum display time, each complete counting and display cycle requires only 0.3 seconds so that almost continuous monitoring is achieved.

When measuring frequencies below 1000 cps greatest accuracy is obtained if the 1-SEC time base is utilized. Although the displayed answers are useful, and in many cases entirely of adequate accuracy, direct measurement of extremely low frequencies is not recommended because of rapidly increasing errors as the frequency is reduced. Ordinarily, frequencies as low as 100 cps, or even 60 cps, will give usable readings, depending upon the accuracy required. See Section V for details of the errors involved.

2-4 Counting or Totalizing

The Model 200 may be used as a simple electronic counter, displaying as the answer the total or aggregate number of input impulses received during any period of time as controlled by manual switch operation. The input signal may be of periodic or pulse form similar to that required for frequency measurement. For such straight counting proceed as follows:

1. Connect the signal to be counted to the INPUT connector.
2. Set the TIME BASE switch to "OFF".
3. Set the COUNT switch to "OFF".
4. Rotate the SENSITIVITY control completely clockwise.
5. Push the MANUAL RESET button to clear the Decade Counting Unit display to 0000.
6. Start trial counting by throwing the COUNT switch to "ON"; stop counting by returning the COUNT switch to "OFF".
7. Reduce the sensitivity by rotating the SENSITIVITY knob counter-clockwise to lowest position which still gives consistent counting.
8. Push the MANUAL RESET button to reset display to 0000.
9. The Model 200 is now adjusted for straight or totalizing counting. Start the count by throwing the COUNT switch to "ON"; stop the count by throwing the COUNT switch to "OFF". The count displayed is the total number of impulses sensed during the period the COUNT switch is left in the "ON" position.

After each count the Model 200 can be reset to 0000 and thus "cleared" for a new count by pushing the MANUAL RESET button. If, however, it is desired that a number of sequential counts be totalized or added together then the MANUAL RESET button is not used between counts and each count is added to the display previously stored in the instrument.

2-5 Input Signal Requirements

All signals for frequency measurement and straight counting are applied to the INPUT connector on the front panel of the Model 200. Some limitations in regard to amplitude, frequency and signal-to-noise ratio are imposed on the input signal. These depend upon the character of the input signal itself.

Periodic input signals such as sine waves, square waves, waves with large percentages of harmonics, etc., must have a minimum amplitude of 0.05 volts rms if their frequency lies between 10 and 100,000 cycles per second. This minimum amplitude must be increased to 0.07 volts rms for frequencies between 1 and 10 cycles per second. No ac input signal greater than 150 volts rms should be applied because of possible damage to the instrument, but dc bias or polarizing voltage up to 400 volts may be applied safely.

For input signals made up of positive-going pulses the minimum amplitude is 0.1 volts peak with the repetition rate extending from 0 to 200,000 pulses per second. The pulses, however, must have a voltage rise characteristic of 0.2 volts or more per second. Two input pulses separated by less than approximately 5 microseconds will not be distinguished and will be recorded as a single count. For negative-going input pulses no minimum peak amplitude can be stated since this is influenced greatly by the negative pulse duty cycle.

In all cases, to reduce erratic or false counting from noise interference it is important that the input signal have as high a signal-to-noise ratio as possible.

2-6 The Sensitivity Control

The SENSITIVITY control on the front panel allows adjustment of the input signal for optimum level. Sensitivity is increased when the knob is rotated in a clockwise direction. When frequency measurement or straight counting is being performed and the input signal contains some noise, the best adjustment of this control is just slightly above the lowest level which gives reliable, consistent counting. Any further increase in sensitivity only increases the probability of erroneous counts due to noise interference. When no noise is present the SENSITIVITY control may be advanced as much as desired. Refer to Paragraph 2-3.

If the SENSITIVITY control is rotated fully counter-clockwise to the TEST position, the input signal is disconnected and internal time base pulses are automatically fed into the input circuits for self-checking the instrument. Control of sensitivity is unnecessary for such tests. Refer to Paragraph 2-2.

2-7 The Gate Time Switch

The GATE TIME switch is used when measuring frequency to select counting time intervals of 0.1 second or 1 second so that the unknown frequency is displayed in terms of "cycles per 0.1 second" or "cycles per second". The optimum switch position is determined by the number of significant figures involved and the accuracy required. For more details refer to Paragraphs 2-3 and 5-3.

2-8 The Display Control

After each automatic count the length of time the answer is displayed across the front panel by the Decade Counting Units is determined by the DISPLAY knob setting. The display period is adjustable from 0.1 second to approximately 10 seconds, the time increasing with clockwise rotation.

At the extreme counter-clockwise position marked "MANUAL" the display time is infinite. In this position the automatic reset circuits are disabled and any answer displayed will be held indefinitely until the MANUAL RESET button is depressed.

2-9 The Time Base Switch

The TIME BASE switch when thrown to "OFF" disconnects all internally generated time base pulses from the internal control circuits. Such is desired when the Model 200 is used for straight or totalizing counting and no time gating functions are required. Throwing the TIME BASE switch to "OFF" also automatically switches the display time control circuits to "MANUAL" so that each count will be held indefinately until the MANUAL RESET button is operated. Refer to Paragraph 2-4.

2-10 The Count Switch

The COUNT switch is used only as a manual gate control for straight or totalizing counting. When the Model 200 has been adjusted for counting as outlined in Paragraph 2-4, counting is started as the switch is set in the "ON" position and counting is stopped when the switch is returned to "OFF". For all frequency and period measurements the COUNT switch is left in the "OFF" position.

2-11 The Manual Reset Button

Pressing the MANUAL RESET button at any time instantly resets all the Decade Counting Units in the display panel to 0000 thus "clearing" the count. All internal control circuits also are reset in preparation for a new count. This resetting action overrides all other controls and clears the display no matter whether actual counting is in progress at the time or not. Interruption of a frequency measurement in such manner does not affect in any way the accuracy of the next measurement and display. The MANUAL RESET button is most useful when the Model 200 is employed as a straight or totalizing counter for which automatic reset is not desired. Refer to Paragraph 2-4.

SECTION III

ACCESSORY TRANSDUCERS AND AUXILIARY EQUIPMENT

3-1 General Applications

In addition to counting or measurement of frequency, the Model 200 when coupled with appropriate transducers can be used for precision measurement of many other physical parameters which vary as functions of time. In industrial applications, for example, shaft speeds can be measured easily in terms of revolutions-per-second or revolutions-per-minute with numerous transducers such as tachometer generators, commutators, switches, photocells, or magnetic or electrostatic pick-ups. With various other type transducers, fuel flow, pressure, displacement, temperature, acceleration, etc., may be measured. Any mechanical, optical or other type function of time which can be converted into electrical impulses by a suitable transducer may be measured equally well.

3-2 Measurement of RPM with a Magnetic Pick-up

The Model 200 measured RPM by indicating a tranducer pick-up signal frequency which is proportional to the shaft speed. One of the simplest transducers is a magnetic pick-up which consists essentially of a coil of wire around a permanent magnet core. The core extends sufficiently beyond one end of the coil so that it may be used as a probe. Magnetic material, such as iron or steel, which passes near the probe causes an electrical pulse to be generated within the coil.

If this pick-up is positioned near a keyway or a gear on a rotating shaft then an output pulse will be delivered each time the keyway or a gear tooth passes beneath the probe. No actual contact with the shaft is necessary, nor is it desired, and there is no loading of the machine under test. Magnetic pick-ups of this type are manufactured by the Electro Products Company, Chicago, Illinois, and the Waugh Engineering Corporation, Van Nuys, California

When the keyway is used for probe excitation there will be one pulse per revolution, and the output frequency measured by the Model 200 will indicate the shaft speed directly in revolutions-per-second. This is converted into revolutions-per-minute merely by multiplying by the factor of 60.

If the magnetic pick-up is activated by a gear, the output frequency measured by the Model 200 will be the true shaft speed in revolutions-per-second multiplied by the number of gear teeth. To convert this to revolutions-per-minute the Model 200 reading in cycles per second must be divided by the gear tooth number and multiplied by 60. This is expressed:

$$\text{RPM} = \frac{\text{Frequency (cps)} \times 60}{N}$$

where N = number of gear teeth

In some cases when it is possible to choose a gear with an arbitrary number of teeth, it is convenient to select a gear tooth number of 60 or 6 or some other factor of 60. By using a 60-tooth gear and operating the Model 200 in frequency measurement with the GATE TIME switch in the 1-SEC position, the count displayed is made to give the RPM directly without calculation. The 6-tooth gear will give a frequency reading in cycles per second which is one-tenth the actual shaft speed in revolutions-per-minute.

3-3 Measurement of RPM with a Photocell Pick-up

A photocell pick-up may be used in a similar way to measure RPM. The end of the rotating shaft must first be painted black or given a light-absorbing surface for half its circumference and painted white or rendered light-reflecting for the other half. The shaft is then illuminated with a strong light and the reflected light picked up by a photoelectric cell.

Output pulses from the photocell may be fed directly into the input of the Model 200. Voltage necessary for photocell operation may be obtained from the Accessory Socket at the rear of the instrument. Refer to Paragraph 3-6 below.

With this type of pick-up the frequency indicated by the Model 200 will be the revolutions per second which require multiplication by 60 to obtain RPM.

For very low speed shaft rotation a greater number of impulses per second can be obtained if several alternate black and white equal surfaces are painted around the shaft circumference. The light source should be restricted so the illuminated spot on the shaft is not larger than a black or white surface. True RPM then is calculated by using a division factor N in exactly the same way as when a number of gear teeth are used with a magnetic pick-up. Refer to Paragraph 3-2 above.

3-4 Fluid Flow Measurement

When used with a turbine-type flow meter the Model 200 measures accurately either total flow or rate of flow of fluids. This type flow meter, which is inserted directly into the fluid line, consists of a small turbine arranged so the tips of the impeller blades pass by the probe of a built-in magnetic pick-up. The rotational speed of the impeller, and hence the frequency of the magnetic pick-up output, is proportional to the fluid flow.

If the Model 200 is operated as a totalizing counter (see Paragraph 2-4) then the read-out is a measure of total fluid flow. When operated as a frequency meter (see Paragraph 2-3) the Model 200 indicates the rate of fluid flow. In each case the digital read-out must be multiplied by a calibration factor furnished by the flow meter manufacturer.

Fluid flow meters of this type are available from the Waugh Engineering Corporation, Van Nuys, California.

3-5 Pressure and Temperature Measurement

The Vibrotron, as made by the Byron-Jackson Company, Los Angeles, California, is one type of transducer which converts variations in pressure into changes of frequency which are readily measured by the Model 200. Some Models of the Vibrotron also can be made sensitive to temperature.

This device operates upon the principle that the natural frequency of vibration of a stretched fine wire can be varied by changing the applied tension. In the Vibrotron one end of the wire is attached to a pressure diaphragm. A pressure change on the diaphragm results in diaphragm movement which alters the wire tension and gives a consequent variation in frequency of vibration. Each new pressure has a corresponding new vibration frequency.

If the diaphragm and wire are made of temperature-sensitive materials, then temperature changes also will result in proportional frequency changes.

The fine wire is arranged to vibrate in a magnetic field supplied by permanent magnets so that a small voltage is generated in the wire. This voltage is amplified and furnished as output. A portion of the amplified voltage also is fed back to the wire, the resulting regeneration maintaining the wire in continuous vibration.

For both pressure and temperature measurements the digital frequency readout given by the Model 200 must be multiplied by suitable calibration factors quoted by the Vibrotron manufacturer to obtain true pressure or temperature values.

3-6 Power for Auxiliary Equipment

A limited amount of filament and plate power is furnished by the Model 200 for operation of pre-amplifiers, photocells, photocell amplifiers, or other auxiliary equipment. Power supply connections are available at pins on the Accessory Socket located on the back panel of the instrument. See Fig. 8.

The Accessory Socket also provides a precisely controlled timing frequency of 10 cps as generated by the internal time base. In addition, means are given to use the Model 200 with an external laboratory frequency standard. These applications are explained in Paragraphs 3-7 and 3-8 below.

The standard timing signal and power supply voltages present on the various Accessory Socket pins are indicated in the schematic diagram of Fig. 9. In tabular form they consist of the following:

Pin 1: Input from laboratory frequency standard (any multiple of 10 cps from 10 to 100 cps.)

Pin 2: Ground

Pin 3: 6.3 vac @ 5 amperes

Pin 4: -150 vdc @ 1 ma. (regulated)

Pin 5: 10 cps from internal time base

Pin 6: +250 vdc @ 24 ma. (unregulated)

Pin 7: 60 cps (from power line)

Pin 8: Input from external gate time generator (negative pulses, 0 - 100,000 pps)

NOTE: The above timing signal and power supply voltages do not apply if a Model XD-100A Crystal Time Base plug-in unit has been added to the Model 200 Frequency Counter. Refer to Paragraph 7-6.

3-7 Use of External Frequency Standard

If desired, the internal time base of the Model 200 may be disabled and an external standard frequency generator used in its place. Referring to Figs. 9 and 12(a), note the three-point terminal strip located at the left end of the instrument chassis adjacent to the Accessory Socket. Removing the wire strap between terminals 1 and 2, then replacing the strap between terminals 2 and 3 disconnects the internal time base and makes use of external signals which are fed into Pin #1 on the Accessory Socket.

External standard frequencies which are acceptable may be of any multiple of 10 cycles per second from 10 cps to 100 cps. These signals should be of square wave or negative pulse form with amplitude of at least 40 volts peak-to-peak.

External gate time signals also may be applied to Pin #8 of the Accessory Socket. In this case it is not necessary to disturb the wiring on the three-point terminal strip. The GATE TIME front panel switch should be placed in the "0.1 SEC" position and TEST SWITCH SW-5 must be rotated to its #0 position (maximum CCW). The external gate time signals may have repetition rates from 0 to 100,000 pulses per second but should be of square wave or negative pulse form with amplitudes of at least 40 volts peak-to-peak.

3-8 The Model 200 as a Standard Frequency Source

When the Model 200 is in operation there is available on Pin #5 of the Accessory Socket a standard frequency signal of 10 cps generated by the internal time base. Refer to Figs. 8 and 9 for location of this socket and connections thereto.

This 10-cps signal consists of negative pulses with amplitudes of approximately 40 volts peak-to-peak, and since it is derived from the 60-cycle power line frequency, has the same nominal accuracy of about $\pm$ 0.1%. If an external frequency standard is used with a Model 200 then the accuracy of the 10-cps timing signal becomes identical to that of the external standard itself.

NOTE: If a Model 200 Frequency Counter contains an XD-100A Crystal Time Base plug-in unit then additional standard frequencies of 100 cps, 1 kc and 10 kc also are available. Refer to Paragraph 7-7.

SECTION IV

THEORY OF OPERATION

4-1 Principal Functions

The Model 200 Frequency Counter is a versatile electronic instrument capable of performing two different functions:

1. Measurement of the frequency of an unknown input signal.

2. Straight or totalizing counting of the number of input signal impulses.

Preparation for each of these functions is made by manipulation of the Model 200 front panel controls and the resulting arrangements of the basic internal circuits are illustrated by block diagrams in Figs. 2 and 3. These will be discussed in order.

4-2 Measurement of Frequency

The frequency of an unknown input signal is measured by counting the cycles (or pulses) of the input signal which occur during an accurately controlled time interval. Interconnections of the major circuits of the Model 200 for such frequency measurement are illustrated in Fig. 2. The operation of these circuits is as follows:

1. The unknown input signal which is applied to the INPUT connector is first fed through the SENSITIVITY control to the Amplifier V-1. In this amplifier low-level signals are given sufficient amplification to operate the following Schmitt Trigger V-2.

2. The Schmitt Trigger V-2 is a special dc-coupled multivibrator or "flip-flop" which generates sharp, constant-level pulses necessary for reliable operation of the decade counters. Although variations in the amplitude of the unknown input signal do not pass beyond this stage, the frequency of the input signal is retained since exactly one pulse is generated for each cycle of the input signal.

3. Signal-controlled pulses then are fed to the Signal Gate stage V-3 which acts as a switch. When the Signal Gate is open, pulses are allowed to pass through to the decade counters; when closed, the flow path is blocked and no pulses for the counters are delivered.

4. The counters consist of four plug-in decade counting units arranged in cascade. Signal pulses from the Signal Gate are applied to the right-hand "units" counter. The "units" counter in turn feeds the "tens" counter, the "tens" counter feeds the "hundreds" counter, and so on. After each frequency measurement the answer is displayed by one lighted numeral in each column of the counters. The decade

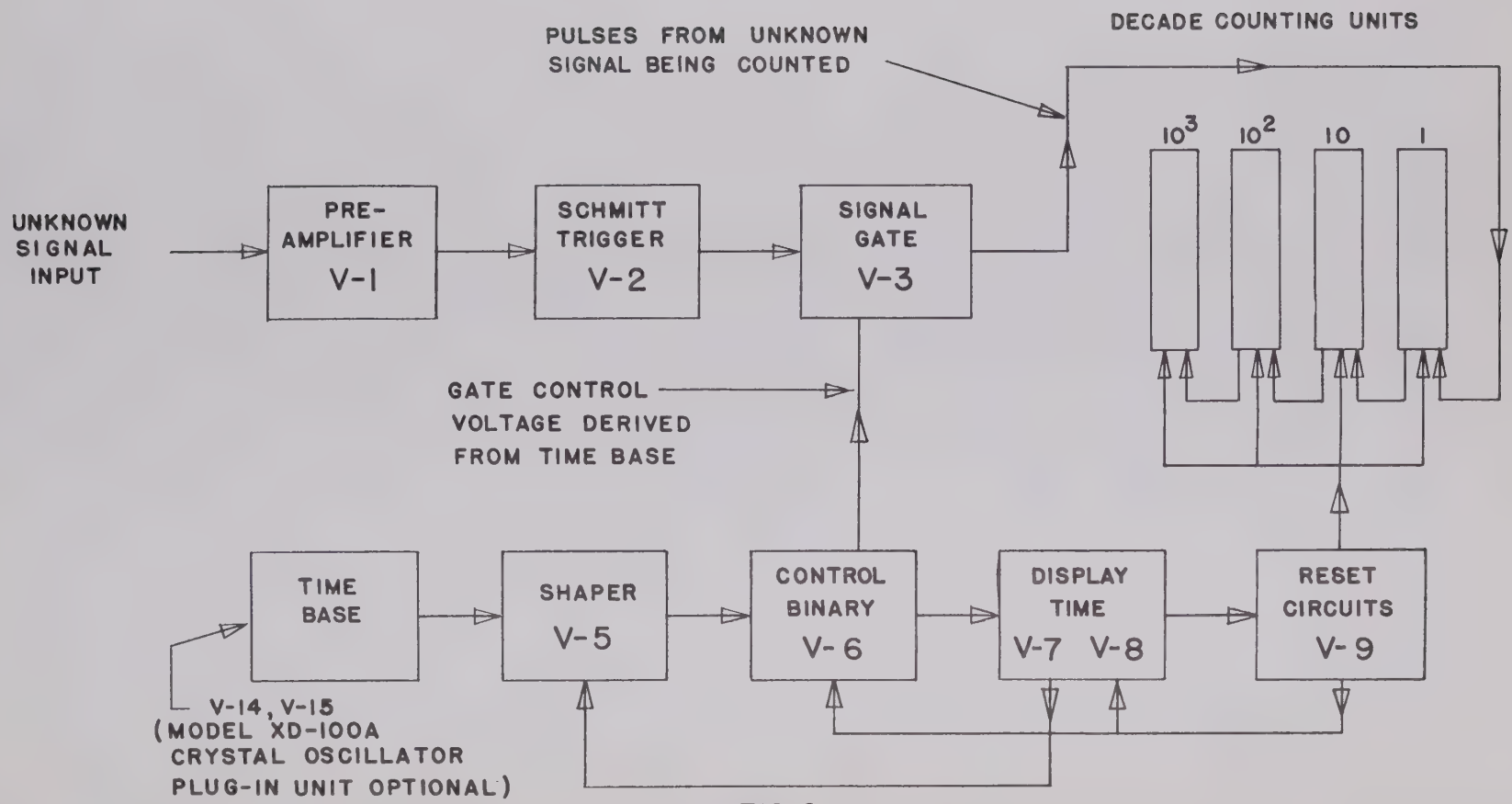


FIG. 2
FUNCTIONAL DIAGRAM
FOR FREQUENCY MEASUREMENT

counting units are "cleared" to zero for a new count either by the automatic reset circuits or by manual operation of the MANUAL RESET push-button.

5. Accurately controlled voltage signals which open and close the Signal Gate V-3 are generated by the Time Base. Two precise control signal lengths are provided: 0.1 second and 1 second. Both signal durations are rigidly controlled by reference to the 60-cps power line frequency.

   NOTE: If the optional XL-100A Crystal Time Base plug-in unit is used then control signal durations are timed by a 100-kc crystal oscillator. See Section VII.

6. The Shaper Amplifier V-5 serves two purposes: (1) it prevents loading of the Time Base circuits and provides constant-level timing pulses to the Control Binary V-6; (2) it performs as a gate or switch, blocking signals from the Time Base so the Control Binary V-6 is not operated during the time a frequency measurement is being displayed by the decade counters. When the display time is over this latching action of V-5 is released, allowing Time Base pulses to operate the Control Binary V-6 for a new count.

7. The Control Binary V-6 provides control voltages which open and close the Signal Gate V-3. After the Shaper V-5 is unlatched, the arrival of the first time base pulse at the Control Binary triggers it into the condition which supplies a positive voltage to the Signal Gate. This opens the Signal Gate and marks the "start" of a counting period. The positive voltage is maintained, keeping the Signal Gate open, until the Control Binary receives a second time base pulse after a precise time interval. This second pulse retriggers the Control Binary, removes the positive voltage and closes the Signal Gate, thus marking the "stop" or end of the counting period.

8. After each counting period the read-out will be maintained in the display on the counters for the length of time determined by the Display Time V-8 circuits. These circuits serve to close the Shaper V-5 so no additional timing signals will be fed to the Control Binary V-6. No new counting can be started and the previous count is retained on the display.

9. Once the display time has elapsed, the Reset V-9 circuits automatically supply a reset pulse to all the decade counters, clearing them to zero. Reset pulses also are applied to the Display V-8 and Control Binary V-6 sections, and finally, the Shaper V-5 is unlatched for a new count.

For a detailed description of operation procedure in measuring frequency refer to Paragraph 2-3.

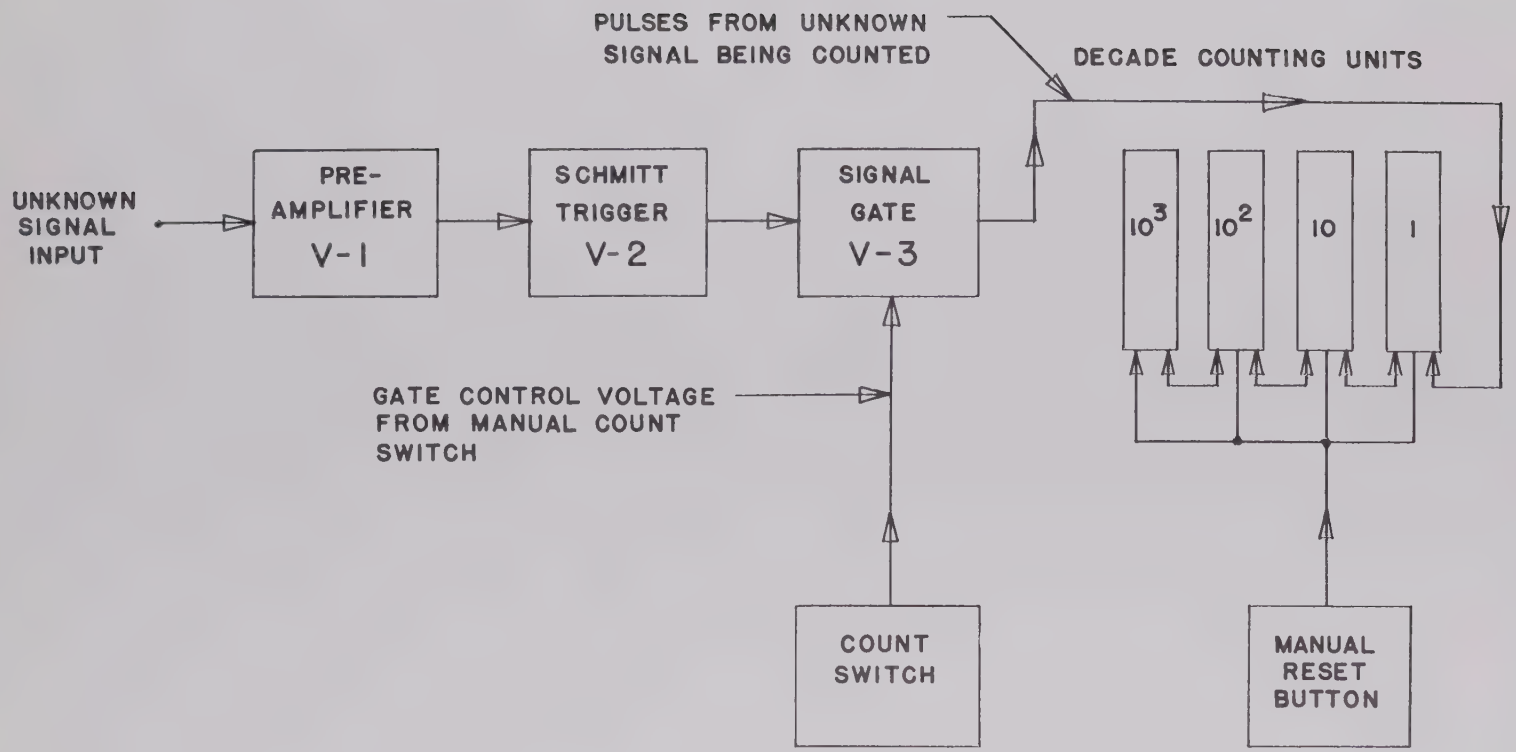


FIG. 3 FUNCTIONAL DIAGRAM FOR COUNTING OR TOTALIZING

4-3 Straight or Totalizing Counting

The internal circuits of the Model 200 are switched into the arrangement outlined by the block diagram in Fig. 3 when used for counting of the number of input signal impulses received. These major circuits perform as below.

1. Input signals to be counted are applied to the INPUT connector which feeds them through the SENSITIVITY control into the amplifier V-1. In the amplifier low-level signals are given sufficient amplification to operate the Schmitt Trigger.

2. The Schmitt Trigger V-2 is a dc-coupled type of multivibrator designed to provide sharp output pulses of constant amplitude which are desirable for consistent, reliable operation of the counters. A single output pulse is delivered to the Signal Gate for each cycle (or pulse) of the input signal.

3. The Signal Gate V-3 is manually opened and closed by means of a front panel toggle switch. When the gate is opened, pulses from the Schmitt Trigger pass through to be counted by the decade counting units connected in cascade. When the Signal Gate is switched closed the pulse path is blocked and the counting is stopped.

4. The numerals displayed by the decade counters at any time represents the total or aggregate count of all input signal pulses which arrive during the time the Signal Gate is left in the open or "count" condition.

   Since the automatic reset circuits have been disabled, the counter display can be cleared to zero only by operation of the MANUAL RESET push-button. Any number of individual counts can be made if the MANUAL RESET button is operated before the start of each count. If no resetting is used, then any new count will be added to the count previously stored in the instrument, giving an over-all or totalized count.

Details of operating procedure for straight or totalized counting are given in Paragraph 2-4.

4-4 The Amplifier

Circuits for the amplifier, Schmitt Trigger and other stages in the control section of the Model 200 may work satisfactorily with low-level unknown input signals, sufficient amplification is supplied to bring such signals up to the amplitude required to operate the Schmitt Trigger V-2. The amplifier V-1, which is a two-stage, resistance-capacity-coupled amplifier, serves this purpose by providing an approximate gain of 175 from about 10 to **100,000 cycles** per second. In this frequency range an input voltage of about 0.05 volts rms, with the SENSITIVITY control R-1 advanced to maximum, will operate the instrument reliably. The gain is somewhat decreased in the frequency range 1 to 10 cycles per second where an input signal of 0.07 volts rms is required.

Even with severe overloading, which results in amplitude clipping at the output, this amplifier is designed to give normal operation of the Model 200 in most instances.

4-5 The Schmitt Trigger

The Schmitt Trigger V-2 is a dc-coupled bi-stable multivibrator or "flip-flop" which generates a single, very sharp, constant-amplitude positive output pulse for each cycle of the input signal coming from the amplifier. without an input signal, the right-hand triode of V-2 normally is conducting, the left-hand triode cut off. As the input signal raises the grid potential of the left-hand triode from its static value of about +55 volts to approximately +63 volts, the Schmitt Trigger suddenly switches conduction states, the left-hand triode now passing plate current, the right-hand triode being cut off. This sudden stopping of plate current through the right-hand triode produces a very sharp positive output pulse which passes through the Signal Gate V-3, if open, to be counted by the decade counting units. As the input signal to the grid of the left-hand triode of the Schmitt Trigger drops in potential to about +62.5 volts the conduction states suddenly revert to the starting condition. The right-hand triode once more is made conducting and the left-hand triode is returned to cut-off. This action produces a negative output pulse, but pulses of such polarity at this point have no effect on the counters.

This generation of a positive pulse which can be counted, and a negative pulse which cannot, is repeated each time the input signal passes through the critical triggering voltages. By such means any amplitude variations in the input signal are prevented from reaching the counters, and the counters are supplied constant-level, sharp pulses for most reliable, accurate counting.

4-6 The Signal Gate

The Signal Gate V-3 is a Type 5915 pentode tube containing two control grids especially designed for gating purposes. If its second control grid is maintained at a high negative voltage with respect to the cathode, any signal impressed on the first control grid will be blocked and will not appear at the plate output. Reducing the second control grid bias to zero allows the tube to perform as a conventional pentode amplifier.

Controlling voltage is applied to the second control grid of the Signal Gate V-3 by means of the dual-triode Clamp and athode Follower V-4. The right-hand triode is a cathode follower used to prevent loading of the Control Binary V-6. The left-hand triode of V-3 is connected as a diode or clamp which insures that the second control grid of the Signal Gate when opened is always driven definitely to zero but never to a variable positive voltage.

When the Signal Gate V-3 is opened and the tube is operating as an amplifier, a 180-degree phase shift is involved so that positive input pulses result in amplified negative output pulses to the decade counters.

4-7 The Decade Counting Units

The counters are one plug-in Model 120C and three plug-in Model 100C Decade Counting Units connected in cascade. Negative pulses from the Signal Gate are fed directly to the "units" counter (Model 120C), the output of which is

fed to the "tens" counter (Model 100C). The "tens" counter output in turn is supplied to the "hundreds" counter, and so on. The count is displayed on the front faces of the decade counting units by means of a single lighted numeral in each of the four columns.

Each plug-in decade counting unit is comprised of four binary "flip-flop" stages in tandem, a resistor matrix, and ten neon indicating lamps. Special feedback loops are included to transform the scale-of-16 count inherent in such binary systems to a 0-to-9 decimal counting system. For construction details and principles of operation of the decade counting units refer to the Appendix attached to this book.

4-8 The Shaper Amplifier

Depending upon the setting of the GATE TIME switch on the front panel of the Model 200, the Shaper V-5 may have input pulses from either the first or second frequency divider stages in the time base section. Since these two input pulses are not necessarily of the same amplitude, the Shaper has been designed as a clipping or limiting amplifier which delivers a constant-level, square-top output signal. This is differentiated into sharp negative pulses, always of the same amplitude, for reliable triggering of the Control Binary V-6.

The Shaper also serves as a gate for blocking trigger signals to the Control Binary after a measurement has been made and the answer is being displayed by the counters. This is accomplished by applying a high negative bias to the control grid of one of the Shaper stages.

The front panel TIME BASE switch SW-3 also is included in the Shaper Amplifier circuits. When no timing signals are needed, as in straight counting, operation of the TIME BASE switch blocks the Shaper Amplifier by placing a high negative bias on one control grid.

4-9 The Control Binary

Control voltages which open and close the Signal Gate V-3 are generated by the Control Binary V-6. This is a "flip-flop" multivibrator having two stable states. When the Model 200 is reset, and a new measurement is to begin, the right-hand triode of the Control Binary V-6 is conducting but the left-hand triode is completely cut off. Under these conditions the plate voltage for the right-hand triode is relatively low, and since this voltage is coupled by means of the Cathode Follower V-4 to the second control grid of the Signal Gate V-3, the Signal Gate is closed and no counting can occur.

When a negative pulse from the Shaper V-5 reaches the Control Binary a rapid triggering action is initiated which results in a reversal of the conduction states. The left-hand triode of the Control Binary is now made conducting and the right-hand triode plate current is reduced to zero. This new state will remain until the circuit is further disturbed. In this condition, the plate voltage for the right-hand triode is relatively high and the increased positive voltage applied to the Signal Gate through the Cathode Follower V-4 is sufficient to open the Signal Gate and allow counting to proceed.

Upon the arrival of a second pulse from the Shaper, the Control Binary triggers again to return to its starting condition. Once more the left-hand triode is cut off and the right-hand triode made to pass plate current. The resulting drop in plate voltage for the right-hand triode is passed through the Cathode Follower to the Signal Gate, thus closing the Signal Gate and stopping the counting action.

4-10 The Latching Binary

The Latching Binary V-7 is another multivibrator flip-flop which has two stable states. At all times, except when an answer is being displayed on the counters, the right-hand triode of the Latching Binary is conducting and the left-hand triode cut off. With the left-hand triode at cut-off there is a high positive voltage present at its plate. This high positive voltage through resistors R-45, R-47 and R-23 is impressed upon one grid of the Shaper V-5 to keep this amplifier circuit operative allowing trigger pulses to reach the Control Binary V-6. The low plate voltage of the right-hand triode is fed through resistors R-51 and R-50 to the control grid of the Display Time tube V-8 so that this tube is held cut-off

The Latching Binary is connected to the Control Binary is such a way that only a negative pulse from the Control Binary will start a triggering action. This occurs after the Control Binary has been triggered once to begin a counting interval and then triggered back to stop the counting action. At this time the Latching Binary also is triggered and its conduction states reversed so that the left-hand triode is conducting and the right-hand triode cut off.

The drop in plate potential for the left-hand triode of the Latching Binary V-7, which is equivalent to a negative voltage increment, passes through resistor R-45, then through CR-4 and finally through resistor R-23 to one grid of the Shaper V-5, the resulting high negative bias completely blocking the Shaper so no further trigger pulses can reach the Control Binary. The rise in plate voltage of the right-hand triode which is applied to the Display Time tube V-8 is delayed by the integrating action of resistor R-51, the Display Time potentiometer R-50 and condenser C-24.

Since the Control Binary no longer can receive triggering pulses, the Latching Binary also cannot be triggered. The Latching Binary remains in this "latched" condition until reset either by the automatic reset circuit or by operation of the MANUAL RESET button.

4-11 The Display Time Circuit

The right-hand triode of Display Time V-8 is a cathode follower with its grid returned to the +200-volt plate supply voltage. The resulting plate current flow maintains both cathodes of V-8 at a high positive potential. During the time interval when actual counting is going on the control grid of the left-hand triode of the Display Time V-8 is held at a low potential derived from the Latching Binary V-7. With a low potential on the grid and a high positive potential on the cathode this tube is cut-off.

At the moment counting is complete the Latching Binary is triggered into its latched condition for the start of the display time. Timing capacitor C-24 begins to charge toward the Latching Binary plate potential through resistor R-51 and the Display control potentiometer R-50. After a definite time delay

the potential of capacitor C-24 reaches the critical value required for the left-hand triode of V-8 to conduct. At this time the conduction states of V-8 are reversed, the right-hand triode is cut off and the left-hand tricde is driven to saturation, its grid current discharging C-24. V-8 then returns to its original conduction state. The resulting plate potential rise of the left-hand triode fires the Reset thyratron V-9. The time delay, which determines the time interval for display, can be varied from 0.1 to 10 seconds by adjustment of the DISPLAY potentiometer R-50.

4-12 The Reset Circuits

When the Reset thyratron V-9 fires the resulting current flow through cathode resistor R-98 developes a sharp pulse of approximately +40 volts peak amplitude which is used to reset the entire Model 200 instrument for another counting measurement. This reset pulse is fed to all four plug-in decade counting units, clearing them to read "0000"; it also is applied to both the Control Binary and the Latching Binary, leaving them in proper conduction states to be triggered for a new counting and display cycle.

If the DISPLAY potentiometer R-50 is rotated fully counter-clockwise to "MANUAL", the switch SW-8 is opened. This removes the grid voltage from the left-hand triode of V-8 to disable the automatic reset circuits, and the Model 200 can be reset only by momentary operation of the MANUAL RESET push-button switch SW-4.

4-13 Delay for the Shaper Amplifier

After the Latching Binary V-7 has been reset, the high negative bias voltage supplied to block the Shaper V-5 and also charge capacitor C-13 has been removed. The negative charge on capacitor C-13, however, cannot disappear rapidly since the discharge current cannot pass through CR-4 but must flow through the high resistance of resistor R-47. This means there is a time delay of approximately 100 microseconds before the Shaper Amplifier can deliver a triggering pulse to the Control Binary for the start of a new counting cycle. This delay is desired so that all transient voltage disturbances caused by resetting the decade counting units will have disappeared and cannot cause errors in the new count measurement.

4-14 The Time Base*

The Time Base section of the Model 200 consists of two Frequency Divider stages which are designated as V-14 and V-15 in Fig. 9. These stages operate upon the 60-cps power line frequency to provide timing pulses having repetition rates of 10 per second and 1 per second for precise Signal Gate Control when the Model 200 is used for measuring frequency.

*NOTE: In Model 200 Frequency Counters containing an XD-100A Crystal Time Base plug-in unit reference to the 60-cps power line frequency is not used and the statements in Paragraph 4-14 do not apply. Refer to Section VII.

The 10-per-second timing pulses are obtained from the first Frequency Divider V-14 which divides the power line frequency of 60 cps by a factor of 6. The second Frequency Divider V-15, in turn, makes a further division by a factor of 10 thus producing the 1-per-second timing pulses. The manner in which these frequency dividers function is described in the following paragraph.

4-15 The Frequency Dividers

The two Frequency Divider stages V-14 and V-15, Fig. 9, successively divide the 60-cps power line frequency into 10-cps and 1-cps timing signal pulses. Both dividers are unistable or "one-shot" multivibrators, and except for components giving different time constants, the circuits and principles of operation for the two stages are identical.

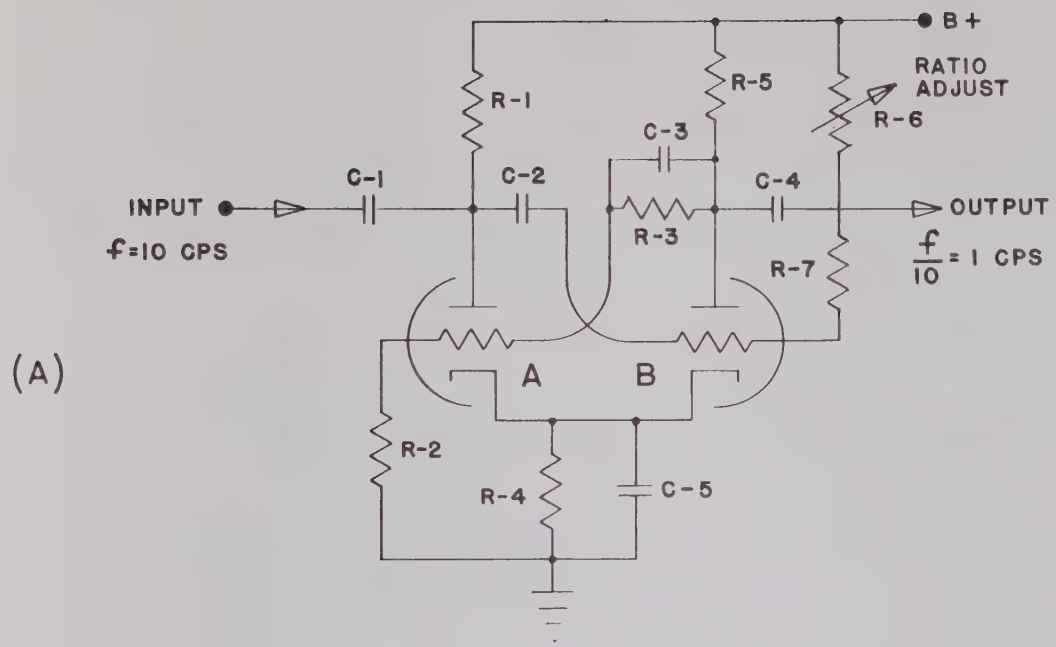
The circuit of a typical frequency divider is given in Fig. 4(a) which shows it to be two triode amplifiers connected so the plate voltage output of triode A is fed to the control grid of triode B, and the plate voltage output of triode B, in turn, is applied back to the grid of triode A. Since the control grid of triode B is connected to the positive high voltage supply through resistors R-6 and R-7 this grid is held at a positive potential allowing substantial current flow. This results in a relatively low plate potential for triode B which is applied through resistor R-3 to the grid of triode A. The heavy plate current flow also maintains a high positive cathode potential for both tubes.

This combination of low grid potential and high cathode potential for triode A is more than adequate for cut off and no plate current flows through this tube. This particular condition of triode A being cut off and triode B conducting is a stable state which will remain indefinitely until the circuit is disturbed.

A positive input pulse arriving at the plate of triode A and grid of triode B through capacitors C-1 and C-2 will have no effect since the grid of triode B already is maintained at a positive potential. A negative pulse, however, tends to reduce the plate current in triode B. This results in an increase in positive voltage at the plate of triode B, which is coupled through resistor R-3 and capacitor C-3 to the grid of triode A. Furthermore, the drop in plate current reduces the positive potential of both cathodes. Under these conditions triode A begins to conduct plate current, and the current flowing through resistor R-1 causes a voltage drop which is coupled through capacitor C-2 to the grid of triode B reducing the plate current in triode B still further. This results in an even greater positive signal to the grid of triode A, and so on.

The action, therefore, is accumulative and in a small fraction of a micro-second the conduction states of the two tubes are interchanged, triode A becoming conducting and triode B being cut off with a large negative charge accumulated on grid capacitor C-2.

The two triodes remain in this state as long as a substantial negative charge is retained on capacitor C-2. But this charge begins to leak off through resistors R-6 and R-7, and at some definite time later, as determined by the capacitor and resistor values, the negative grid bias for triode B decreases to the point at which plate current can flow. Once plate current is initiated in triode B a reverse switching action takes place to restore triode B to a



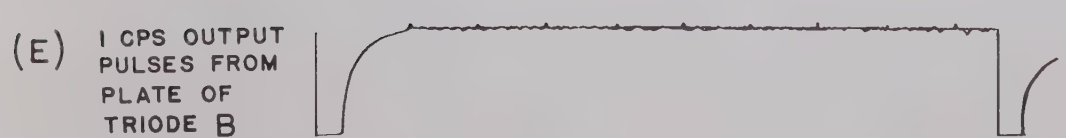


FIG. 4

TYPICAL FREQUENCY DIVIDER AND WAVEFORMS

conduction state and return triode A to the cut-off condition. The circuit then will remain in this initial stable state until another negative input pulse is received.

How this time delay characteristic is used for frequency division is illustrated in Figs. 4(b), 4(c), and 4(d). The input signal to the frequency divider may be 10-cps pulses as shown in Fig. 4(b). After differentiation in capacitor C-1 of Fig. 4(a) these 10-cps pulses appear as seen in Fig. 4(c) and are used in this form to trigger the frequency divider.

As pictured in Fig. 4(d) the first negative input pulse switches the divider leaving a large negative charge on capacitor C-2 connected to the grid of triode B. This negative charge leaks off exponentially, but since only a very small portion of the exponential discharge characteristic is used, the grid voltage appears to decrease almost linearly with respect to time. During this interval the divider is not sensitive to input pulses. If the time constants of the circuit, as determined by the setting of potentiometer R-6, are adjusted properly, the grid bias of triode B will decrease just sufficiently to permit reverse switching of the circuit precisely at the proper instant to be triggered again by the tenth input pulse.

For these conditions the plate voltage output from triode B appears as in Fig. 4(e), and since there is one output pulse for every ten original input pulses shown in Fig. 4(b) an accurate frequency division of 10-to-1 is obtained. In a frequency divider of this type it is possible to realize almost any integral ratio of frequency division such as 3, 4, 6, 7, 9, 11, 15-to-1, etc., the exact ratio being controlled by the circuit time constants.

To make allowances for tube variations, potentiometer R-6 normally has a limited range of adjustment giving ratios of 9-to-1 and 11-to-1 for extreme positions so that the desired 10-to-1 ratio is found near mid-center position. Or if a 6-to-1 division is required, potentiometer R-6 at extreme positions is made to give ratios of 5-to-1 and 7-to-1. Procedures for adjustment of both frequency dividers in the Model 200 are outlined in Paragraph 7-4.

NOTE: Frequency divider adjustment procedures for Model 200's utilizing the XD-100A Crystal Time Base plug-in unit are given in Paragraph 7-4.

4-16 The Self-Test Circuits

The Model 200 contains built-in test circuits which permit the operator's checking the performance of the instrument at any time regardless of the position of the Gate Time Switch. These test circuits also make it possible to check and adjust both frequency divider stages without auxiliary test equipment.

Whenever the SENSITIVITY control, indicated as R-1 in the general schematic diagram Fig. 9, is rotated fully counter-clockwise to "TEST" the input grid of the Pre-amplifier V-1 is connected directly to the junction of resistors R-2 and R-3. Double-pole switch SW-7 also is operated to remove any external input signal and at the same time remove the short circuit across resistor R-2 allowing internally generated test signals to be applied directly into the input of the Pre-amplifier.

If the GATE TIME switch is in the 0.1-SEC position, a 60-cps test signal is applied to the input and the Signal Gate is opened for 0.1 second which should result in a test display of 0006. For the 1-SEC position of the GATE TIME switch the same 60-cps test signal is gated through for a period of 1 second which will give a display of 0060 for proper operation.

Obtaining the correct display count for both positions of the GATE TIME switch as explained above indicates that all frequency dividers, pre-amplifier, gate, gate control, latching, display and counter circuits are performing properly. The entire instrument thus is automatically inspected.

In the event a frequency divider is malfunctioning, as evidenced by an incorrect test display number, each divider can be checked individually by making use of the GATE TIME switch on the front panel. If the GATE TIME switch is in the 0.1 SEC position the output of the first frequency divider only is used to obtain the correct test display number. If incorrect operation is indicated the necessary adjustment can be made at that point. The GATE TIME switch then is rotated to its 1 SEC position for test of the subsequent frequency divider stage. Detailed instructions for alignment of both frequency divider stages are given in Paragraph 6-4.

NOTE: Model 200 Frequency Counters containing the XD-100A Crystal Time Base plug-in unit do not utilize the self-test display numbers described above. Methods of frequency divider alignment also differ. For such instruments refer to Paragraphs 7-4 and 7-5 in Section VII.

SECTION V

ERRORS AND ACCURACIES

5-1 Major Sources of Error

The Model 200 Frequency Counter is a digital instrument incorporating an electronic gate which controls over a precise period of time the input signals fed to several cascade-connected decade counting units. With a gating function of this sort there is always a "gating error" which is inherent in the system and which cannot be avoided. The magnitude of the error depends greatly upon the frequency of the unknown input signal. When operated properly, the gating error of the Model 200 can be reduced to an extremely low value.

An additional error can be traced to the 60-cps power line frequency which is employed as a precise time or frequency standard within the instrument. In most localities the accuracy of the power line frequency may be assumed to be $\pm$ 0.1% which often can be considered insignificant compared with the gating error. Nevertheless, if in certain circumstances the gating error can be reduced to the same order of magnitude, the small power line frequency error should be considered for very precise measurement.

In the following paragraphs the natures of these errors are discussed and methods are described for reducing them to a minimum.

5-2 Power Line Frequency Time Base Error

In most areas of the United States the frequency of the nominal 60-cps 117-volt electric power is maintained sufficiently well to guarantee an accuracy of $\pm$ 0.1%. In some regions, however, this may not be true, and for absolute surety it is recommended the local power company be contacted for reliable information.

Since the entire time base section of the Model 200 is controlled by the power line frequency, any error present in the latter is automatically carried through and applied directly to any measurements made by the Model 200 itself. Thus, an error of $\pm$ 0.1% in power line frequency means a possible error of $\pm$ 0.1% in Model 200 readout.

Time base error is not influenced by any gating error which may be present. Total possible error, therefore, is the sum of time base error and gating error, whatever it may be, or simply:

$$\text{Total error (\%)} = 0.1\% \pm \text{gating error (\%)}$$

NOTE: If a Model 200 Frequency Counter contains an XD-100A Crystal Time Base plug-in unit the time base error is reduced to 0.0001%. Since gating error usually is several orders of magnitude greater, this extremely small crystal oscillator error ordinarily can be ignored. Only when gating error drops to the order of $\pm$ 0.01% need the time base error

be considered.....in which case the crystal error is simply added directly to the gating error as before. Refer to Paragraph 5-4 and 7-1.

5-3 Gating Errors

When the Model 200 is measuring frequency the unknown input signal pulses pass through the electronic gate which is opened for a precise time as controlled by the instrument's time base. Since the period of the pulses being counted and the period during which the gate is open are completely independent, no integral ratio between these two can be expected. This completely random relationship leads to an inherent possible gating error of + 1 count or - 1 count, but not both. This is illustrated in Fig. 5. With a given input signal pulse rate and a definite gate open time as in Fig. 5(a), the time relationship may be such that only two pulses are counted. But if the gate open time is shifted slightly with respect to the input pulses, it is possible that three pulses are counted as in Fig. 5(b).

The magnitude of gating error is determined in the case of frequency measurement by the gate time selected and whether the frequency is high or low. This error in per cent may be expressed as follows:

Frequency Measurement

$$\text{Error } \% = \frac{\pm \text{ 1 count}}{\text{Gate Time}} \times 100 = \frac{\pm \text{ Period of unknown frequency (f)}}{\text{Gate Time}} \times 100$$

$$\text{or Error } \% = \frac{\pm 100}{\text{Unknown frequency (f)} \times \text{Gate Time}}$$

In frequency measurement the Model 200 permits gate open times of 0.1 and 1 second. Errors for each of these then are:

$$\text{Error } \% = \pm \frac{10^3}{f} \qquad \text{(0.1-second gate)}$$

$$\text{Error } \% = \pm \frac{10^2}{f} \qquad \text{(1-second gate)}$$

Frequency Measurement

5-4 Total Errors

As stated earlier, if the time base error described in Paragraph 5-2 is added to the gating error discussed in Paragraph 5-3 then the total possible error is obtained. This may be put in equation form:

$$\text{Total Error } \% = \pm 0.1 \pm \frac{10^3}{f} \qquad \text{(0.1-second gate)}$$

$$\text{Total Error } \% = \pm 0.1 \pm \frac{10^2}{f} \qquad \text{(1-second gate)}$$

These two errors plotted with respect to the unknown signal frequency (f) give the solid-line curves shown in Fig. 6.

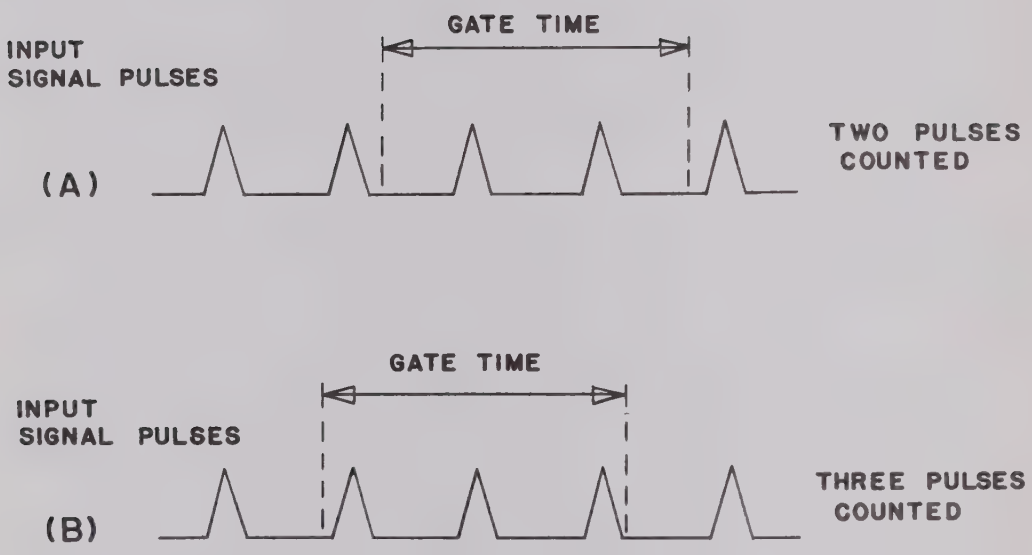


FIG. 5

SOURCE OF $\pm$ 1 COUNT GATING ERROR

Inspection of these curves points out the fact that serious errors are involved in frequency measurement of extremely low frequencies, but these errors decrease rapidly and approach a limiting value of 0.1% as the frequency is increased. This value of 0.1% is the constant time base error which remains even when the gating error becomes insignificant.

The curves also indicate that when low frequencies are to be measured by the Model 200 considerably more accuracy is obtained by using the 1-SEC position rather than the 0.1-SEC position of the GATE TIME switch.

It is interesting to note the dotted curves in Fig. 6. These represent possible errors due to gating alone. If a Model 200 Frequency Counter contains an XD-100A Crystal Time Base plug-in unit, the time base error is reduced to $\pm$ 0.0001%. But since the dotted curves in Fig. 6 show gating error alone usually is several orders of magnitude greater, this extremely small crystal oscillator error ordinarily can be ignored. The dotted curves in Fig. 6, therefore, very nearly represent the total errors experienced when using such a crystal oscillator time base instead of the 60-cycle power line. Only when gating error drops to the order of $\pm$ 0.01% need the crystal error be considered. These values are much too small to be seen on the curves on Fig. 6.

For details of operation of the Model 200 Frequency Counter with an XD-100A Crystal Time Base plug-in unit refer to Section VII.

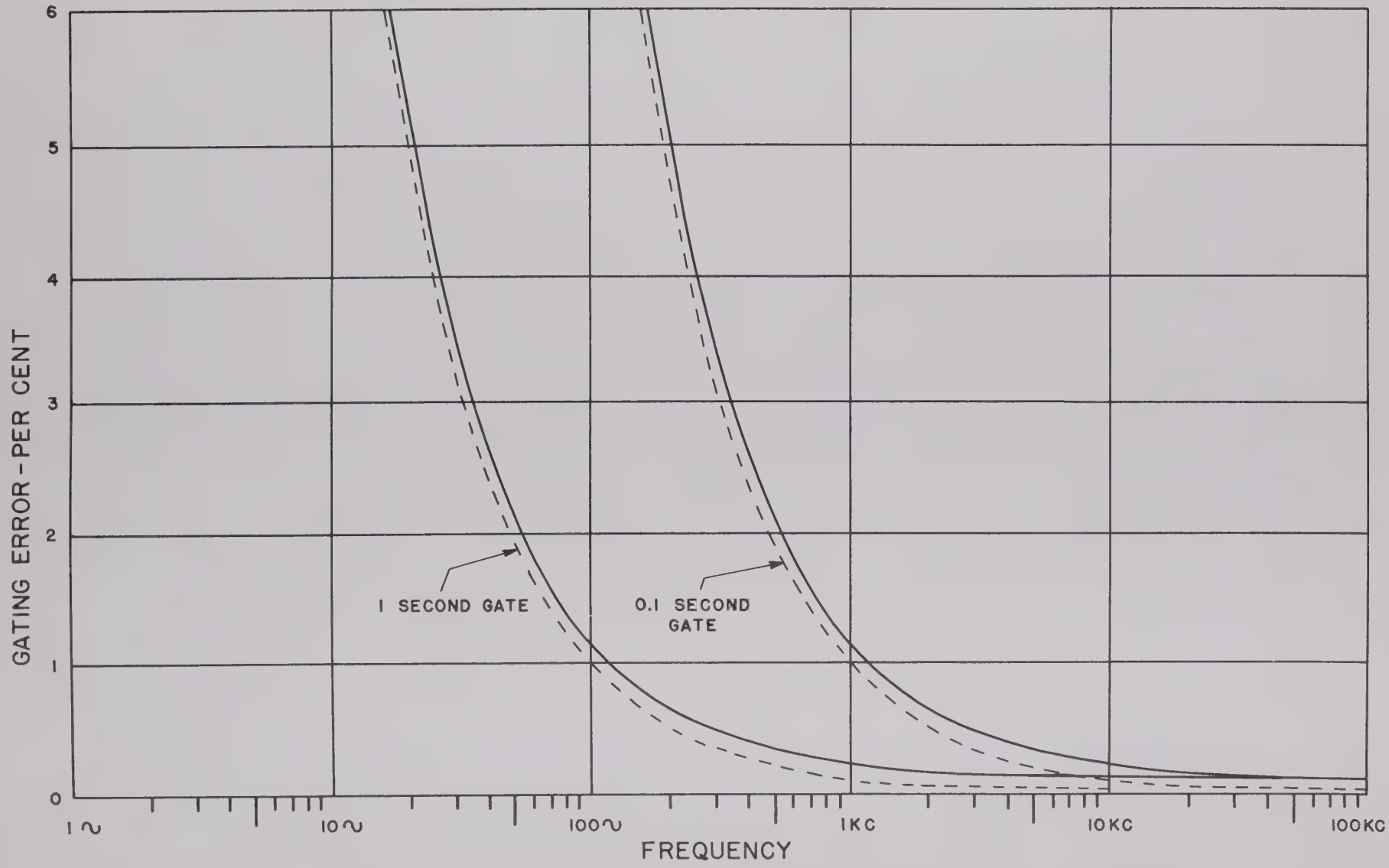


FIG. 6 ERRORS VS FREQUENCY

SECTION VI

MAINTENANCE

6-1 General Maintenance

The Model 200 Frequency Counter is an extremely stable instrument, adequately cooled by an over-large fan, and containing a built-in regulated power supply which insures normal operation over line voltage variations between 105 and 130 volts. Aside from actual failure of components, the Model 200 should require a minimum of maintenance or servicing.

Occasionally, however, whenever tube performance should fall due to ageing or when tubes are replaced, it is desirable that minor adjustments be made for optimum operation. These adjustments, which are described in detail in the following paragraphs, include setting the voltage of the regulated power supply, calibration of the display time circuits and alignment of the time base frequency dividers.

6-2 Setting the Power Supply Voltage

In order to set the regulated power supply voltage, the top cover of the Model 200 first must be removed.

1. At the left end of the instrument locate the 10-point terminal strip at the bottom of the vertical chassis. Note the 10th terminal nearest the back of the Model 200 to which red wires are attached. Clip the POSITIVE test lead of an accurate voltmeter to this point.

2. Attach the NEGATIVE test lead of the voltmeter to any convenient chassis ground.

3. Locate Voltage Control Potentiometer R-88 situated on the main chassis between V-11 (6AV5) and V-13 (0A2). Adjust Potentiometer R-88 for a voltmeter reading of exactly +200 volts d. c.
   Note: Regulated voltage increases for clockwise (CW) rotation of Potentiometer R-88.

6-4 Frequency Divider Adjustment

If at any time, due to ageing or replacement of tubes, should the "self-test" feature of the Model 200 give an incorrect display reading, thus indicating malfunction of one or both frequency dividers, each of these dividers may be adjusted readily without auxiliary equipment. It is recommended that the dividers be adjusted, one at a time, in the order of their operation in the circuits. The procedure for accomplishing this is outlined below in both step-by-step and tabular form:

1. Turn SENSITIVITY knob to "TEST".
2. Turn GATE TIME switch to "0.1 SEC".
3. Set TIME BASE switch to "ON".
4. Set COUNT switch to "OFF".
5. Adjust DISPLAY knob for display time of about 1 second or longer.

*6. Adjust the 10-cps Frequency Divider Control for Test display count of 0006. (Both frequency divider controls are accessible at rear of the cabinet. See fig. 8).

7. Rotate the GATE TIME switch to the "1-SEC" position.

*8. Adjust the 1-cps Frequency Divider Control for count of 0060.

*IMPORTANT: For maximum stability, a frequency divider control should be turned slowly in one direction to find one limit position for correct count, then turned slowly in the opposite direction to locate the second limit position. For final adjustment the control is then centered approximately between these two limit positions.

GATE TIME Switch Position	Test Count Display	Frequency Divider to be Adjusted
0.1 SEC	0006	10-cps
1.0 SEC	0060	1-cps

*NOTE: The above frequency divider adjustment procedures and the test display numbers cited do not apply if a Model 200 Frequency Counter has been modified by the addition of an XD-100A Crystal Time Base plug-in unit. For instruments of this type refer to Paragraph 7-4 in Section VII.

SECTION VII

CRYSTAL TIME BASE OPERATION

7-1 Time Base Modification

The Model 200 Frequency Counter utilizes time base circuits which generate Signal Gate control voltage frequencies of 10 cycles per second and 1 cycle per second. These permit Signal Gate open-time durations of 0.1 SEC and 1 SEC as selected by the GATE TIME switch on the front panel.

In the unmodified Model 200 these 10-cps and 1-cps frequencies are produced by two frequency dividers which divide the 60-cycle-per-second power line frequency initially by a factor of 6 and then by a factor of 10. Since the 60-cps power line frequency directly controls the two dividers, their 10-cps and 1-cps output signals have exactly the same accuracy as the power line itself, namely about $\pm$ 0.1%.

In many cases this nominal $\pm$ 0.1% accuracy is entirely adequate for routine frequency measurements by the Model 200. In other instances, particularly when gating error can be reduced to a small order of magnitude, the possible time base error becomes the limiting factor for precision measurements. The errors and accuracies involved for various circumstances are listed in Section V and curves showing the relation between errors and frequency are given in Fig. 6.

Time base errors can be reduced from $\pm$ 0.1% to the almost negligible figure of $\pm$ 0.0001% by installing a Model XD-100A Crystal Time Base plug-in unit. This self-contained unit can be installed quickly and easily in the field, the only tool required being a screwdriver.

Once a Model XD-100A plug-in unit is installed, the time base of the Model 200 is no longer referred to the power line 60-cps frequency; instead, reference is made to a precision 100-kc quartz crystal oscillator with the crystal itself housed in a temperature-controlled oven for utmost stability. The Model XD-100A unit also contains three additional frequency dividers which successively divide the 100-kc oscillator frequency into 10-kc, 1-kc and 100-cps signals.

The 100-cps signal is fed to the first frequency divider in the Model 200 in lieu of the original 60-cps from the power line. The first frequency divider now is made to divide by a factor of 10 (instead of 6) so as to produce the same time base output signal of 10 cps as before but with one hundred times more accuracy.

Since the entire time base reference for the Model 200 is changed and three more frequency dividers are included in the XD-100A Crystal Time Base plug-in unit itself, the procedures for frequency divider alignment are modified. Test display numbers obtained when self-checking the instrument also are changed. A description of the Model XD-100A Crystal Time Base plug-in unit with complete instructions for installation and making necessary adjustments are given in the following paragraphs.

7-2 The XD-100A Crystal Time Base Plug-in Unit

In Fig. 14 is shown a schematic circuit diagram of the XD-100A Crystal Controlled Time Base plug-in unit. It consists of a 100-kc quartz crystal oscillator V-1, a Buffer Amplifier V-2, and three Frequency Dividers, V-3, V-4 and V-5, which divide in successive order the 100-kc crystal frequency into 10-kc, 1-kc and 100-cps signals.

The Oscillator V-1 uses a twin-triode tube in a highly stabilized circuit employing feedback between the two tube cathodes. The quartz crystal Y-1, which is inserted in the feedback loop, operates in series resonance thereby restricting feedback voltages for maintaining oscillation to very narrow limits around the crystal frequency of 100kc. This type oscillator minimizes errors due to stray capacity, tube parameter variations, etc. When the crystal is housed in its temperature-controlled oven, short term stability of the oscillator is of the order of 1 part per million. Long term stability is approximately 5 parts per million per week.

For extreme precision, the trimmer capacitor C-1 may be used to vary the oscillator frequency over a limited range of about $\pm$ 8 cycles per second. This allows extremely close calibration when the oscillator is "zero beat" against standard frequency broadcasts from the National Bureau of Standards Station WWV, Arlington, Virginia. Refer to Paragraph 7-8 for oscillator calibration procedure.

The Buffer Amplifier V-2 is used principally to isolate the Crystal Oscillator V-1 from the following frequency divider stages, preventing changes in loading from affecting the oscillator accuracy. This amplifier also blocks voltage pulses and spikes from the frequency dividers which could feed back into the oscillator circuit. As another feature, the Buffer Amplifier acts as a clipper or limiter and delivers an output of square-top waveform which is easily differentiated into sharp pulses for driving the frequency dividers.

The three Frequency Divider stages V-3, V-4 and V-5 are all unistable or "one-shot" multivibrators, and except for components giving different time constants, the circuits and principles of operation are identical. Frequency dividers of this type were discussed in detail in Paragraph 4-15, Section IV.

7-3 Installing the XD-100A Crystal Time Base Plug-in Unit

To install the Model XD-100A Crystal Time Base plug-in unit the top cover of the Model 200 Frequency Counter first is removed and the 60-cycle Time Base Plug pulled out from the Time Base Socket. When viewed from the top, this Time Base Socket is located near the rear of the instrument adjacent to the vertical chassis. Refer to Fig. 7.

Removal of the 60-cycle Time Base Plug (which will no longer be used) automatically disconnects all 60-cps power line time base circuits.

The XD-100A Crystal Time Base unit then is inserted in the Time Base Socket and secured to the vertical chassis by a single mounting screw. The position of the XD-100A after installation is indicated by the dotted outline in Fig. 7.

When the XD-100A plug-in unit has been secured the Model 200 top cover may be replaced since all frequency divider and crystal oscillator adjustments can be made at the rear of the instrument cabinet. See Fig.8.

7-4 Frequency Divider Adjustment in the Modified Model 200

Frequency divider adjustment procedures previously given in Paragraph 6-4 are not valid and cannot be applied to a Model 200 Frequency Counter containing an XD-100A Crystal Time Base plug-in unit. Methods of adjustment must be modified to apply to the three frequency dividers of the XD-100A plug-in unit as well as the two frequency dividers on the chassis of the Model 200 itself.

It is recommended that all frequency dividers be adjusted, one at a time, in the order of their operation in the circuits. The procedure for accomplishing this is outlined below in both step-by-step and tabular form:

1. Turn SENSITIVITY knob to "TEST".

2. Turn GATE TIME switch to "0.1 SEC".

3. Set TIME BASE switch to "ON".

4. Set COUNT switch to "OFF".

5. Adjust DISPLAY knob for display time of about 1 second or longer.

6. Rotate Test Switch SW-5 to its #1 position (next to its #0 maximum CCW position)

   (Test Switch SW-5 is located at the rear of the cabinet and can be operated readily with a short screwdriver. See Fig. 8.)

*7. Adjust the 10-kc Frequency Divider Control for count of 0010. (All frequency divider controls are accessible at rear of the cabinet. See Fig. 8.)

8. Rotate Test Switch SW-5 one step clockwise (CW) to position #2....adjust the 1-kc Frequency Divider Control for count of 0100.

9. Rotate Test Switch SW-5 one step CW to position #3.....adjust the 100-cps Frequency Divider Control for count of 1000.

10. Rotate Test Switch SW-5 to maximum CW position #4. LEAVE IN THIS POSITION.....adjust the 10-cps Frequency Divider for count of 0000.

*NOTE: For maximum stability, all frequency divider controls should be turned slowly in one direction to find one limit position for correct count. then turned slowly in the opposite direction to locate the second limit position. For final adjustment the control is then centered approximately between these two limit positions.

11. Turn GATE TIME knob to "1 SEC".....adjust 1-cps Frequency Divider Control for count of 0100.

GATE TIME Switch Position	*Test Switch SW-5 Position	Test Count Display	Frequency Divider to be Adjusted
**	#0 (Max. CCW)	**	**
0.1 SEC	#1	0010	10-kc
0.1 SEC	#2	0100	1-kc
0.1 SEC	#3	1000	100-cps
0.1 SEC	#4 (Max. CW)	0000	10-cps
1 SEC	#4	0100	1-cps

* Leave Test Switch SW-5 in position #4 for normal operation
** Used only for External Gate Time Signals

7-5 Self-Checking the Modified Model 200

After a Model 200 Frequency Counter has been modified by installation of an XD-100A Crystal Time Base plug-in unit, the self-test frequencies quoted in Paragraph 4-16 are no longer used. Modified conditions are such that when self-checking with the GATE TIME switch in the 0.1-SEC position a 100-kc test signal is applied to the input and the Signal Gate is opened for 0.1 second which should result in a test display of 0000. For the 1-SEC position of the GATE TIME switch a 100-cps test signal is gated through for a period of 1 second which will give a display of 0100 for proper operation.

The test display numbers given in Paragraph 2-2, therefore, are not applicable to a modified instrument. Self-checking of a modified Model 200 should be done as follows:

1. Set the TIME BASE switch to "ON".

2. Set the COUNT switch to "OFF".

*3. Rotate the DISPLAY knob near, but not quite, to its full counter-clockwise position for short display time and automatic operation.

4. Rotate the SENSITIVITY knob to its extreme counter-clockwise position marked "TEST".

*NOTE: When the DISPLAY knob is rotated fully to its extreme counter-clockwise position marked MANUAL the display time is infinite. For this condition the automatic reset is disabled; any count displayed will be held indefinitely and the instrument must be reset manually by pressing the MANUAL RESET button.

5. Rotate the GATE TIME knob to its extreme counter-clockwise position of "0.1 SEC". The number displayed on the front panel should now read "0000".

6. Rotate the GATE TIME knob clockwise to its other setting of "1 SEC". This position now should give a test reading of "0100".

7-6 Auxiliary Equipment Power from the Modified Model 200

As the installation of a Model XD-100A Crystal Time Base unit in a Model 200 Frequency Counter increases slightly the plate and filament power taken from the instrument's power supply, surplus power available for auxiliary equipment as listed in Paragraph 3-6 must be reduced in proportion.

The installation of the XD-100A unit, however, makes available four additional standard timing signals which may be used with external equipment.

Timing signals and power supply voltages are available at the Accessory Socket on the back panel of the Model 200. See Figs. 8 and 9. The modified signals or voltages present on the various socket pins are as follows:

Pin 1: Input from laboratory frequency standard (any multiple of 10 cps from 10 to 100 cps).

Pin 2: Ground.

Pin 3: 6.3 v.a.c. @ 2.3 amperes.

Pin 4: -150 v.d.c. @ 1 ma. (regulated).

Pin 5: 10 cps, 100 cps, 1 kc or 10 kc from internal time base.

Pin 6: +250 v.d.c. @ 24 ma. (unregulated).

Pin 7: 100 kc from internal time base.

Pin 8: Input from external gate time generator (negative pulses, 0 - 100,000 pps)

7-7 Modified Model 200 as a Standard Frequency Source

When the Model 200 is in normal operating condition there is available on Pin #5 of the Accessory Socket a standard frequency signal of 10 cps generated by the internal time base. In an instrument containing an XD-100A Crystal Time Base unit this same Pin #5 also will supply frequencies of 100 cps, 1 kc or 10 kc, depending upon the position of Test Switch SW-5 located on the rear panel. See Figs 8 and 9. The frequencies supplied for each Test Switch SW-5 position are as follows:

Test Switch SW-5 Position	Standard Frequency on Pin #5 of Accessory Socket
#0 (Max. CCW)	*External signal applied to Pin #8
#1	10 kc
#2	1 kc
#3	100 cps
**#4 (Max. CW)	10 cps

*See Paragraph 3-7

All the above standard frequency signals consist of negative pulses with amplitudes of approximately 40 volts peak-to-peak.

An additional standard frequency of 100 kc from the internal XD-100A Time Base is supplied to Pin #7 of the Accessory Socket. This signal is present at all times and is not dependent upon the mode of operation of the modified Model 200. The signal is presented in distorted square wave form, rich in harmonics, with an amplitude of about 90 volts peak-to-peak.

This 100-kc output is essentially of high impedance and Pin #7 should not be loaded with a resistance less than about 220,000 ohms. Excessive loading on Pin #7 causes a reduced 100-kc input to the first frequency divider in the XD-100A Time Base and may result in malfunctioning. As a precaution, at any time the 100-kc signal from Pin #7 is used, the modified Model 200 first should be self-checked to determine if operation is normal. Should an erratic test display be obtained the frequency dividers should be readjusted, preferably with the load applied to Pin #7 of the Accessory Socket. For frequency divider alignment procedure refer to Paragraph 7-4.

7-8 Calibration of the Crystal Oscillator

Due to its extreme stability, the crystal oscillator within the Model XD-100A Crystal Time Base plug-in unit usually does not require calibration for most frequency measurements with the modified Model 200 Frequency Counter. If, however, the Oscillator tube V-1 in Fig. 14 is replaced or the utmost in precision is required, the crystal oscillator may be calibrated easily either by "zero-beating" with standard frequency transmissions from the National Bureau of Standards Station WWV in Arlington, Virginia, or by comparison with an external 100-kc laboratory frequency standard. The procedures for these two calibration methods are outlined below:

NOTE: Normal operation of the modified Model 200 is possible only when Test Switch SW-5 is in the #4 position (maximum clockwise rotation). At other positions of the Test Switch the gate times as indicated by the front panel GATE TIME switch will be in error.

Calibration with 100-kc Laboratory Frequency Standard:

1. Turn on the power for the modified Model 200 and allow to warm up for 30 minutes.

2. Self-check the instrument as described in Paragraph 7-5 to determine if all frequency dividers are operating properly. If malfunction is indicated adjust all frequency dividers as instructed in Paragraph 7-4.

3. As directed in Paragraph 2-3, adjust all controls of the Model 200 for the measurement of frequency.

4. To the INPUT connector apply 100-kc signals from the laboratory standard. The resulting frequency measurement should give a read-out of exactly 0000.

5. If incorrect read-out is displayed, adjust crystal oscillator trimmer condenser C-1, Fig. 14, until the desired read-out of 0000 is obtained.
(Trimmer condenser C-1 is located at the rear of the instrument as shown in Fig. 8.)

With this method of calibration the crystal oscillator is adjusted to have an error of less than 1 cycle per second when compared to the laboratory standard.

Calibration with WWV Standard Frequency Transmissions:

1. Turn on the power for the Model 200 and allow to warm up for 30 minutes.

2. With an 8-pin octal-type plug inserted in the Accessory Socket at the back panel of the Model 200, attach a wire to Pin #7.

3. Connect this wire through a 50 mmf capacitor to the antenna post of a short wave receiver. (If more convenient, instead of using the capacitor make a "gimmick" by wrapping the wire three or four times around the antenna lead-in.)

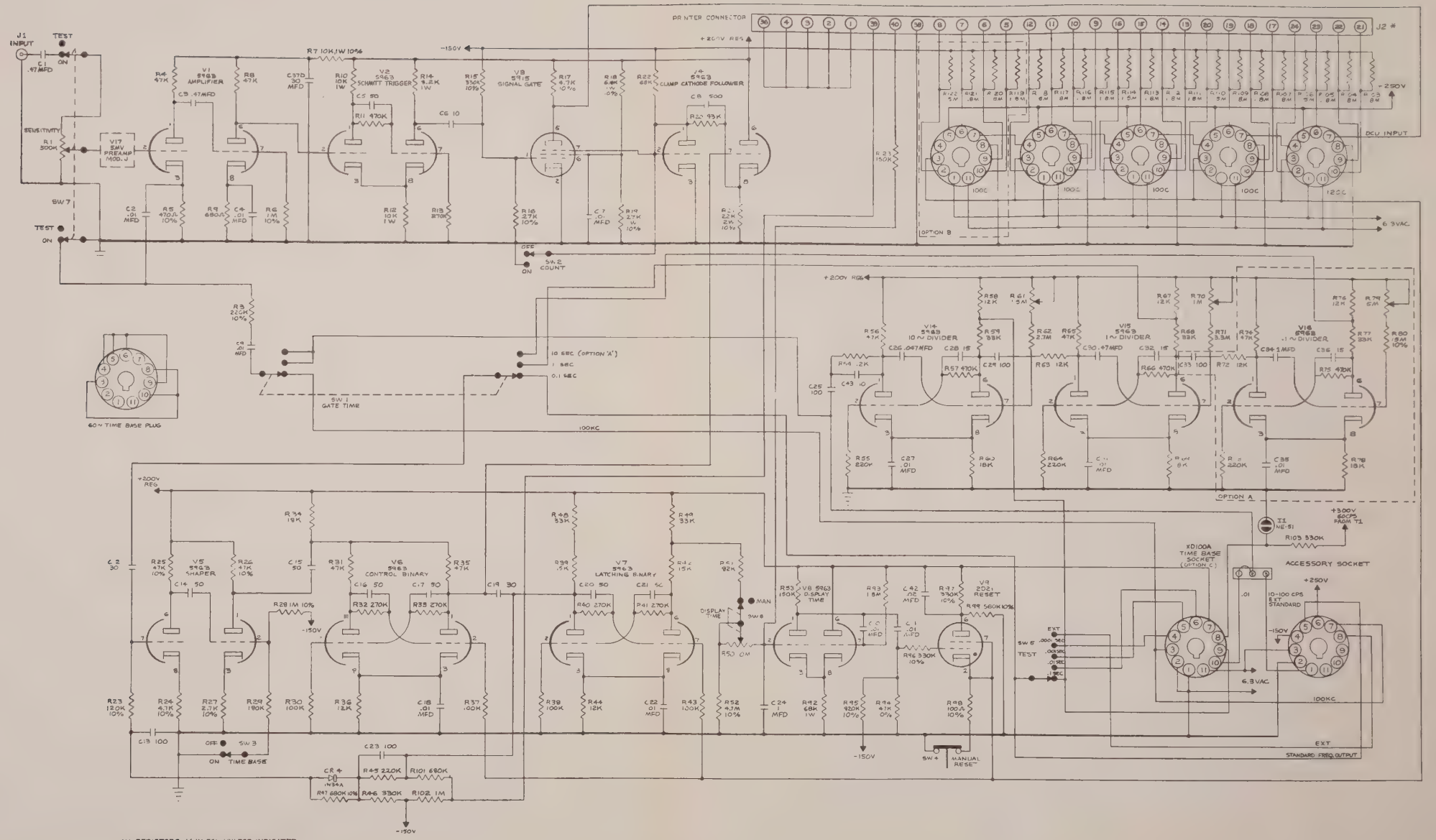
4. Tune the short wave receiver to WWV transmissions on 2.5, 5, 10, 15, 20, 25, 30 or 35 megacycles.

5. During the 1-minute intervals occurring every five minutes when the transmitted carrier is UNMODULATED, listen for a beat note. If no beat note is apparent, adjust trimmer capacitor C-1 until a distinct beat tone is heard. See Fig. 8 for location of C-1.

6. Finally adjust trimmer capacitor C-1 until the beat note drops in frequency below 25 cycles and becomes inaudible.

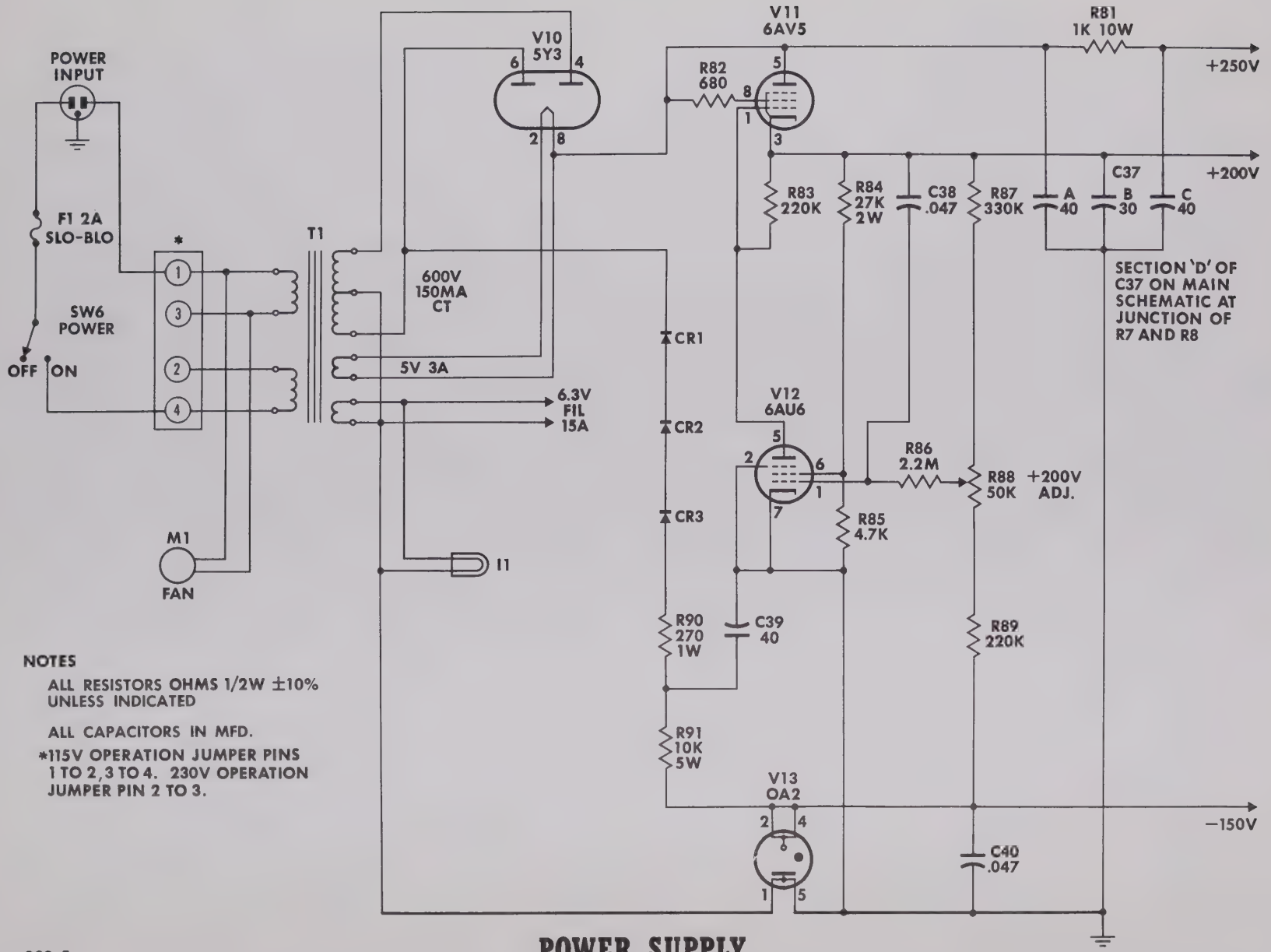
Since higher order harmonics of the 100-kc time base within the modified Model 200 are used in this calibration method, the maximum error involved depends upon the particular carrier frequency of WWV which is being received and the lowest audio frequency which can be passed through the audio amplifier section of the short wave receiver. If it is assumed the beat note cannot be heard when below 25 cycles per second, the maximum calibration errors for the crystal oscillator are as tabulated below:

WWV Standard Transmission Carrier Frequency	Maximum Error in 100-kc Crystal Oscillator for 25-cps Beat Note
2.5 mc	1.000 cps
5.0	0.500
10.0	0.250
15.0	0.166
20.0	0.125
25.0	0.100
30.0	0.083
35.0	0.071



ALL RESISTORS ½W 5% UNLESS INDICATED
ALL CAPACITORS MMFD UNLESS INDICATED
* CANNON DPX-40-34S (MATES WITH CANNON DPX-40-33P)

MODEL 200B
FREQUENCY COUNTER SCHEMATIC



NOTES

ALL RESISTORS OHMS 1/2W ±10% UNLESS INDICATED

ALL CAPACITORS IN MFD.

*115V OPERATION JUMPER PINS 1 TO 2, 3 TO 4. 230V OPERATION JUMPER PIN 2 TO 3.

POWER SUPPLY

Figure 9

VOLTAGE AND RESISTANCE READINGS

Unless otherwise noted all Resistance and Voltage measurements should be made with front panel controls in the following position:

DISPLAY TIME - CCW BUT NOT TO MANUAL
GATE TIME - 1 SEC.
SENSITIVITY - MINIMUM BUT NOT TO TEST
TIME BASE - OFF
COUNT - OFF

Voltage Readings taken with 20,000Ω/volt meter except those otherwise indicated. Momentarily depress manual reset before each voltage reading (after voltmeter is connected to desired test point) ALL VOLTAGES AND RESISTANCES MEASURED TO GROUND.

Tube	PIN 1	2	3	4	5	6	7	8	9
V-1	+45V 75K	0 0	+1.2V 470Ω	Fil	Fil	+67V 75K	0 1 MEG.	+1.5V 680Ω	Fil
V-2	+200V 24K	+52V 85K	+74V 10K	Fil	Fil	+142V 22K	+72V 200K	+74V 10K	Fil
V-3	-10V 27K	0 0	Fil	Fil	+200V 19K	+150V 15K	-32V (0) 55K	---	---
V-4	-32V (0) 55K	-32V (0) 55K	0 0	Fil	Fil	+200V 14K	+44V (120V) 76K	+50V (125V) 20K	Fil
V-5	+200V 60K	-130V 1 MEG.	0 2.7K	Fil	Fil	+56V +200V] 60K	+14V* -25V*] 950K	+15V 0] 4.7K	Fil
V-6	+42V (120) 60K	+26V (+11) 85K	+25V (+25) 12K	Fil	Fil	+120V (+44V) 60K	+11V (+26V) 85K	+25V (+25V) 12K	Fil
V-7	+144V +52V] 50K	+16V +34V] 85K	+35V +34V] 12K	Fil	Fil	+60V +170V] 56K	+35V +15V] 85K	+35V +34V] 12K	Fil
V-8	+200V 200K	+100V 100K	+175V 68K	Fil	Fil	+200V 12K	+170V 1.8 MEG	+175V 68K	Fil
V-9	-6.2V 200K	+1.5V 270Ω	Fil	Fil	+1.5V 270Ω	+120V 270K	+1.5V 270Ω	---	---

NOTE: ( ) = GATE TIME
] = DISPLAY TIME
* = VACUUM TUBE VOLTMETER

Tube	1	2	3	4	5	6	7	8	9	10	11
V-10	N.C.	+290V 15K	N.C.	300VAC 50Ω	N.C.	300VAC 50Ω	Tie Point	+290V 15K	---	---	---
V-11	+190V 260K	Fil	+200V 14K	N.C.	+290V 15K	N.C.	Fil	+290V 16K	---	---	---
V-12	-1.5V 2.5MEG	0 0	Fil	Fil	+190V 260K	+27V 4.5K	0 0	---	---	---	---
V-13	0	-150V 66K	N.C.	-160V 66K	0	N.C.	-150V 66K	---	---	---	---
V-14	+75AVG 65K	42AVG 170K	+44AVG 18K	Fil	Fil	+170AVG 56K	-10AVG* 4MEG	+44AVG 18K	Fil	---	---
V-15	+68V 65K	+42V 170K	+42V 18K	Fil	Fil	+180V 56K	-10* 4MEG	+42V 18K	Fil	---	---
V-16 (optional)	+68V 65K	+42V 170K	+42V 18K	Fil	Fil	+180V 56K	-10* 15MEG	+42V 18K	Fil	---	---
First Decade	Fil	-22V 700K	+1.5V 270 Ω	+135V 68K	+270V 12K	-22V 700K	+200V 18K	0 0	-22V 700K	-20V 700K	Fil
Decades	Fil	-22V 700K	+1.5V 270 Ω	+135V 68K	+270V 12K	-22V 700K	+135V 68K	0 0	-22V 700K	-20V 700K	Fil
Time Base	0	0	50VAC 33K	+190V 28K	+190V 28K	+190V 28K	+200V 14K	50VAC 330K	+190V 28K	+50VAC 330K	6.3VAC 0

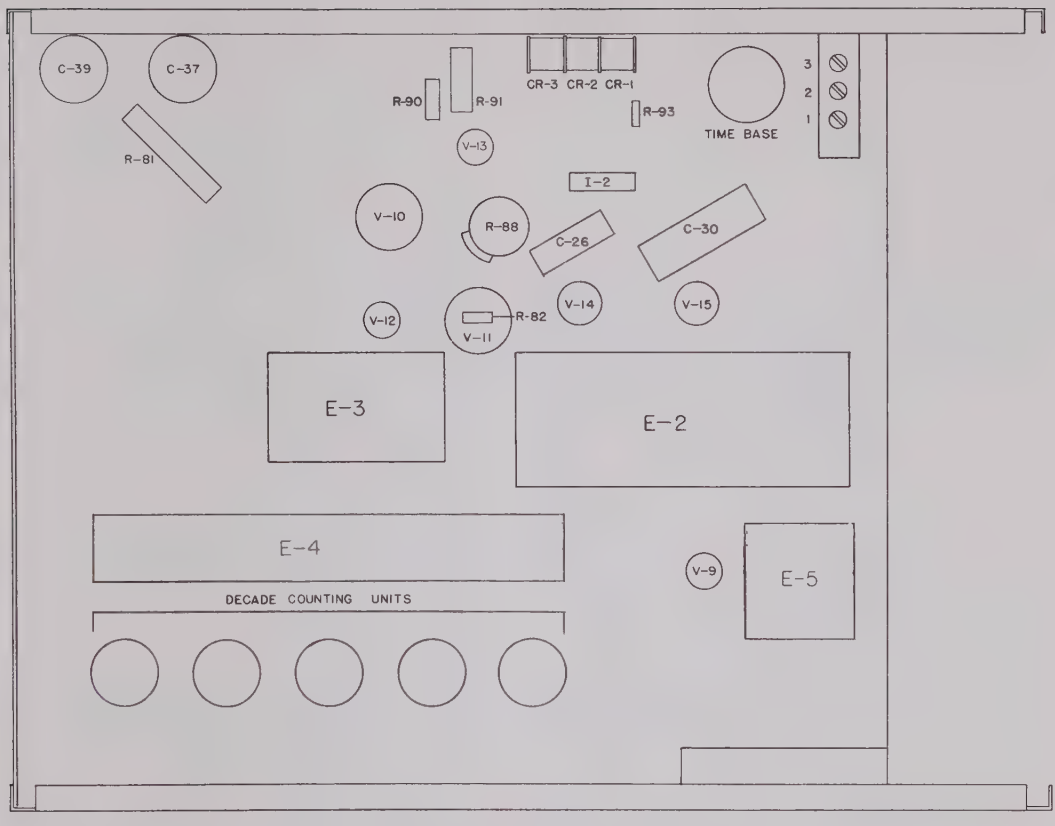


FIG. 10
CHASSIS LAYOUT

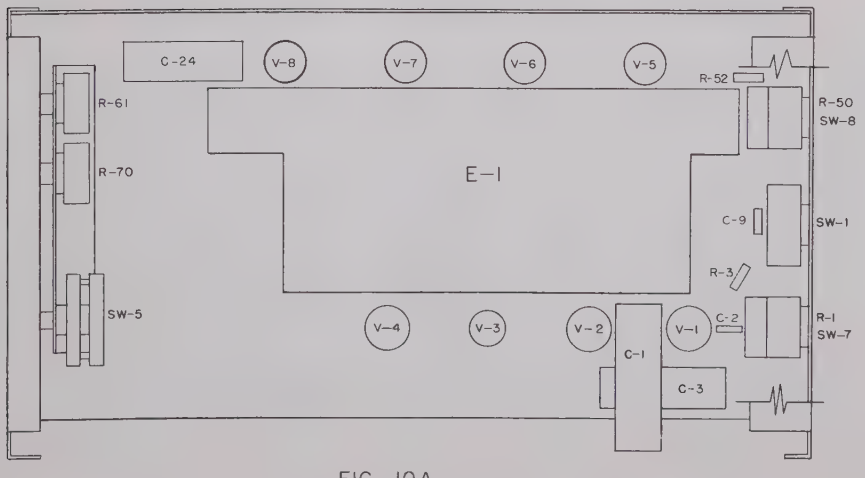


FIG. 10A
VERTICAL CHASSIS

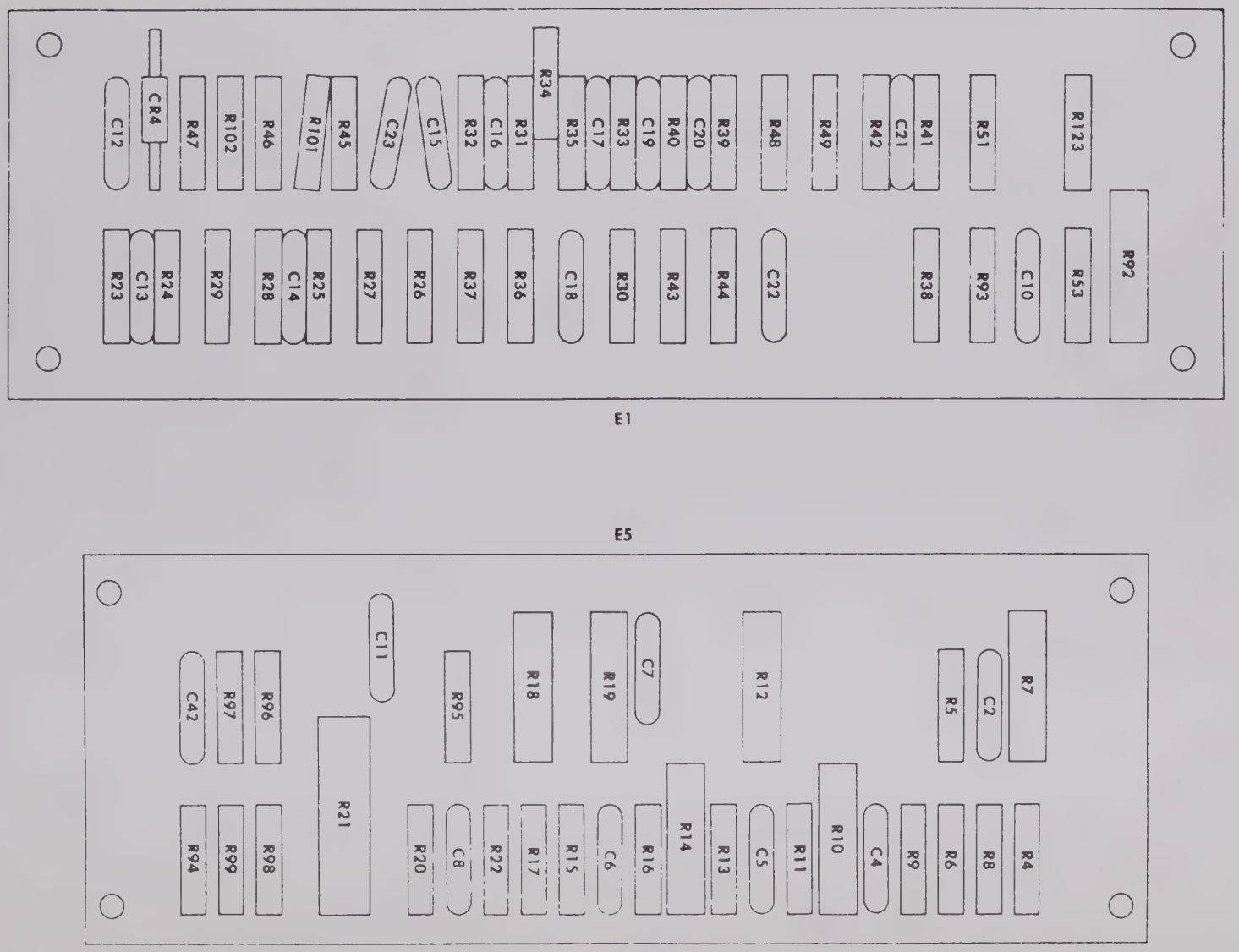
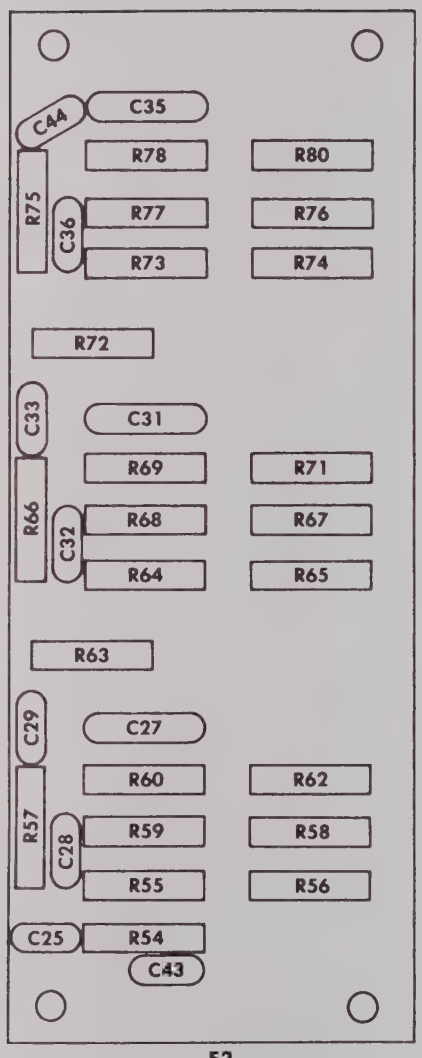
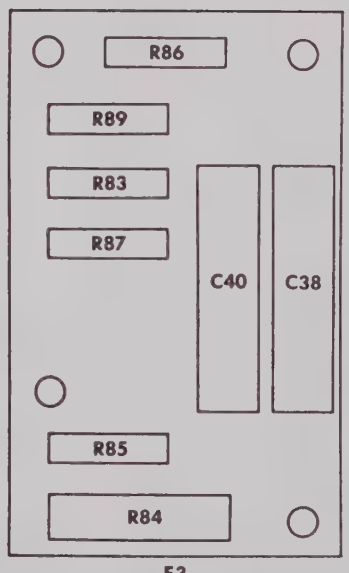


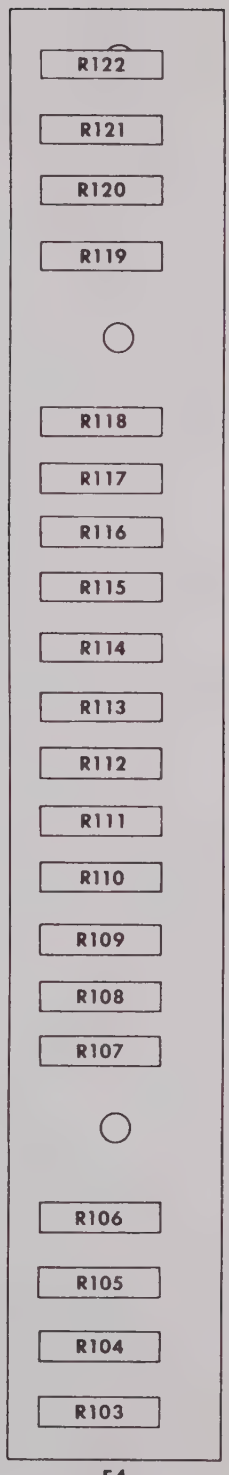
FIG. 11 COMPONENT BOARD PARTS IDENTIFICATION



E2



E3



E4

201-7

FIG.11A COMPONENT BOARDS, PARTS IDENTIFICATION

MODEL 200B

PARTS LIST

MANUFACTURER'S CODE

00853 - Sangamo Electric Company, Capacitor Division, Marion, Illinois
01121 - Allen-Bradley Company, Milwaukee 4, Wisconsin
02979 - Computer Measurements Company, Sylmar, California
05624 - Barber-Colman Company, Rockford, Illinois
24455 - General Electric Company, Lamp Division of Consumer Products Group, Nela Park, Cleveland, Ohio
37942 - P. R. Mallory and Company, Inc., Indianapolis, Indiana
44655 - Ohmite Manufacturing Company, Skokie, Illinois
56289 - Sprague Electric Company, North Adams, Massachusetts
71590 - Centralab Division of Globe Union, Inc., Milwaukee, Wisconsin
72136 - Electro-Motive Manufacturing Company, Inc., Willimantic, Connecticut
72982 - Erie Resistor Corporation, Erie, Pennsylvania
75915 - Littelfuse, Inc,, Des Plaines, Illinois
77638 - Radio Receptor Company, Inc., Brooklyn, New York
82389 - Switchcraft, Inc., Chicago, Illinois
86684 - Radio Corporation of America, Electron Tube Division, Harrison, New Jersey
88026 - Cutler-Hammer, Inc,, Los Angeles, California
91146 - Cannon Electric Company, Eastern Division, Salem, Massachusetts
91637 - Dale Products, Inc., Columbus, Nebraska
93332 - Sylvania Electric Products, Inc., Semiconductor Products Division, Woburn, Massachusetts

Symbol No.	Description	CMC Part No.	Mfg. Part No.	Mfg. Code
C1	CAPACITOR, fixed tubular .47mfd 20% 400WV	C11-474	3304047	00853
C2	CAPACITOR, fixed disc .01mfd GMV 500WV	C1-103	ED-.01	72982
C3	CAPACITOR, fixed tubular .47mfd 20% 200WV	C10-474	67P47402	56289
C4	CAPACITOR, fixed disc .01mf GMV 500WV	C1-103	ED-.01	72982
C5	CAPACITOR, fixed mica 50pf 5% 500WV	C52-500	DM15E-500J	72136
C6	CAPACITOR, fixed mica 10pf 5% 500WV	C52-100	DM15C-100J	72136
C7	CAPACITOR, fixed disc .01mfd 500WV GMV	C1-103	ED-.01	72982
C8	CAPACITOR, fixed mica 500pf 5% 500WV	C63-501	DM19C-501K	72136
C9-C11	CAPACITOR, fixed disc .01mfd GMV 500WV	C1-103	ED-.01	72982
C12	CAPACITOR, fixed mica 20pf 5% 500WV	C52-300	DM15E-300J	72136
C13	CAPACITOR, fixed mica 100pf 5% 500WV	C52-101	DM15F-101J	72136
C14-C17	CAPACITOR, fixed mica 50pf 5% 500WV	C52-500	DM15E-500J	72136
C18	CAPACITOR, fixed disc .01mfd GMV 500WV	C1-103	ED-.01	72982
C19	CAPACITOR, fixed mica 30pf 5% 500WV	C52-300	DM15E-300J	72136
C20-C21	CAPACITOR, fixed mica 50pf 5% 500WV	C52-500	DM15F-500J	72136
C22	CAPACITOR, fixed disc .01mfd GMV 500WV	C1-103	ED-.01	72982
C23	CAPACITOR, fixed mica 100pf 5% 500WV	C52-101	DM15F-101J	72136
C24	CAPACITOR, fixed vitamin Q 1.0mfd 20% 200WV	C10-105	88P1050252	56289
C25	CAPACITOR, fixed mica 100pf 5% 500WV	C52-101	DM15F-101J	72136
C26	CAPACITOR, fixed paper .047mfd 10% 200WV	C20-473	67P47392	56289
C27	CAPACITOR, fixed disc .01mfd GMV 500WV	C1-103	ED-.01	72982

Symbol No.	Description	CMC Part No.	Mfg. Part No.	Mfg. Code
C28	CAPACITOR, fixed mica 15pf 5% 500WV	C52-150	DM15E-150J	72136
C29	CAPACITOR, fixed mica 100pf 5% 500WV	C52-101	DM15F-101J	72136
C30	CAPACITOR, fixed paper .47mfd 10% 200WV	C20-474	67P47492	56289
C31	CAPACITOR, fixed disc .01mfd GMV 500WV	C1-103	ED-.01	72982
C32	CAPACITOR, fixed mica 15pf 5% 500WV	C52-150	DM15E-150J	72136
C33	CAPACITOR, fixed mica 100mfd 5% 500WV	C52-101	DM15F-101J	72136
C37	CAPACITOR, fixed electrolytic 30,30,40,40, mfd; 350/350/450/450 WV	C31-03	TVL4720	56289
C38	CAPACITOR, fixed tubular .047mfd 20% 400WV	C11-473	67P47304	56289
C39	CAPACITOR, fixed electrolytic 40mfd 450WV	C31-01	TVL1725P	56289
C40	CAPACITOR, fixed tubular .047mfd 20% 400WV	C11-473	67P47304	56289
C41	CAPACITOR, fixed disc .01mfd GMV 500WV	C1-103	ED-.01	72982
C42	CAPACITOR, fixed disc .02mfd GMV 500WV	C1-203	DD-203	71590
C44	CAPACITOR, fixed mica 39pf 5% 500WV	C52-390	DM15E-390J	72136
C43	CAPACITOR, fixed mica 10pf 5% 500WV	C52-100	DM15C-100J	72136
CR1-CR3	RECTIFIER, selenium	G-102	8Y1	77638
CR4	DIODE, germanium	G-100	1N34A	93332
F1	FUSE, slo-blo 2 amp 3AG	E2-01	313002	75915
I1	LAMP, incandescent	T2-09	47	24455
I2	LAMP, neon	T2-07	NE-51	24455
J1	CONNECTOR, BNC	E3-05	UG-625/U	91146
J2	CONNECTOR, 40 pin	E3-23	DPX-40-34S	91146
M1	MOTOR, fan	J1	DYAB-5693AD	05624
R1	RESISTOR, variable composition, part of SW7 500K 1/2W 20%	V-101		02979
R3	RESISTOR, fixed composition 220K 1/2W 10%	R10-224	EB2241	01121
R4	RESISTOR, fixed composition 47K 1/2W 5%	R9-473	EB4735	01121
R5	RESISTOR, fixed composition 470Ω 1/2W 10%	R10-471	EB4711	01121
R6	RESISTOR, fixed composition 1 Meg 1/2W 10%	R10-105	EB1051	01121
R7	RESISTOR, fixed composition 10K 1W 5%	R13-103	GB1031	01121
R8	RESISTOR, fixed composition 47K 1/2W 5%	R9-473	EB4735	01121
R9	RESISTOR, fixed composition 680Ω 1/2W 5%	R9-681	EB6815	01121
R10	RESISTOR, fixed composition 10K 1W 5%	R13-103	GB1035	01121
R11	RESISTOR, fixed composition 470K 1/2W 5%	R9-474	EB4745	01121
R12	RESISTOR, fixed composition 10K 1W 5%	R13-103	GB1035	01121
R13	RESISTOR, fixed composition 270K 1/2W 5%	R9-274	EB2745	01121
R14	RESISTOR, fixed composition 8.2K 1W 5%	R13-822	GB8225	01121
R15	RESISTOR, fixed composition 330K 1/2W 10%	R10-334	EB3341	01121
R16	RESISTOR, fixed composition 27K 1/2W 10%	R10-273	EB2731	01121
R17	RESISTOR, fixed composition 4.7K 1/2W 10%	R10-472	EB4721	01121
R18	RESISTOR, fixed composition 6.8K 1W 10%	R14-682	GB6821	01121
R19	RESISTOR, fixed composition 27K 1W 10%	R14-273	GB2731	01121
R20	RESISTOR, fixed composition 43K 1/2W 5%	R9-433	EB4335	01121
R21	RESISTOR, fixed composition 22K 2W 10%	R17-223	HB2231	01121
R22	RESISTOR, fixed composition 68K 1/2W 5%	R9-683	EB6835	01121

Symbol No.	Description	CMC Part No.	Mfg. Part No.	Mfg. Code
R23	RESISTOR, fixed composition 120K 1/2W 10%	R10-124	EB1241	01121
R24	RESISTOR, fixed composition 4.7K 1/2W 10%	R10-472	EB4721	01121
R25-R26	RESISTOR, fixed composition 47K 1/2W 10%	R10-473	EB4731	01121
R27	RESISTOR, fixed composition 2.7K 1/2W 10%	R10-272	EB2721	01121
R28	RESISTOR, fixed composition 1 Meg 1/2W 10%	R10-105	EB1051	01121
R29	RESISTOR, fixed composition 180K 1/2W 5%	R9-184	EB1845	01121
R30	RESISTOR, fixed composition 100K 1/2W 5%	R9-104	EB1045	01121
R31	RESISTOR, fixed composition 47K 1/2W 5%	R9-473	EB4735	01121
R32-R33	RESISTOR, fixed composition 270K 1/2W 5%	R9-274	EB2745	01121
R34	RESISTOR, fixed composition 18K 1/2W 5%	R9-183	EB1835	01121
R35	RESISTOR, fixed composition 47K 1/2W 5%	R9-473	EB4735	01121
R36	RESISTOR, fixed composition 12K 1/2W 5%	R9-123	EB1235	01121
R37-R38	RESISTOR, fixed composition 100K1/2W 5%	R9-104	EB1045	01121
R39	RESISTOR, fixed composition 15K 1/2W 5%	R9-153	EB1535	01121
R40-R41	RESISTOR, fixed composition 270K 1/2W 5%	R9-274	EB2745	01121
R42	RESISTOR, fixed composition 15K 1/2W 5%	R9-153	EB1535	01121
R43	RESISTOR, fixed composition 100K 1/2W 5%	R9-104	EB1045	01121
R44	RESISTOR, fixed composition 12K 1/2W 5%	R9-123	EB1235	01121
R45	RESISTOR, fixed composition 220K 1/2W 5%	R9-224	EB2245	01121
R46	RESISTOR, fixed composition 330K 1/2W 5%	R9-334	EB3345	01121
R47	RESISTOR, fixed composition 680K 1/2W 10%	R10-684	EB6841	01121
R48-R49	RESISTOR, fixed composition 33K 1/2W 5%	R9-333	EB3335	01121
R50	RESISTOR, variable composition, part of SW8 10 Meg 1/2W 20%	V-100	V-100	02979
R51	RESISTOR, fixed composition 82K 1/2W 5%	R9-823	EB8235	01121
R52	RESISTOR, fixed composition 4.7Meg 1/2W 10%	R10-475	EB4751	01121
R53	RESISTOR, fixed composition 150K 1/2W 5%	R9-154	EB1545	01121
R54	RESISTOR, fixed composition 12K 1/2W 5%	R9-123	EB1235	01121
R55	RESISTOR, fixed composition 220K 1/2W 5%	R9-224	EB2245	01121
R56	RESISTOR, fixed composition 47K 1/2W 5%	R9-473	EB4735	01121
R57	RESISTOR, fixed composition 470K 1/2W 5%	R9-474	EB4745	01121
R58	RESISTOR, fixed composition 12K 1/2W 5%	R9-123	EB1235	01121
R59	RESISTOR, fixed composition 33K 1/2W 5%	R9-333	EB3335	01121
R60	RESISTOR, fixed composition 18K 1/2W 5%	R9-183	EB1835	01121
R61	RESISTOR, variable composition 1.5 Meg 1/2W 20%	V-108	V-108	02979
R62	RESISTOR, fixed composition 3.6Meg 1/2W 5%	R9-365	EB3655	01121
R63	RESISTOR, fixed composition 12K 1/2W 5%	R9-123	EB1235	01121
R64	RESISTOR, fixed composition 220K 1/2W 5%	R9-224	EB2245	01121
R65	RESISTOR, fixed composition 47K 1/2W 5%	R9-473	EB4735	01121
R66	RESISTOR, fixed composition 470K 1/2W 5%	R9-474	EB4745	01121
R67	RESISTOR, fixed composition 12K 1/2W 5%	R9-123	EB1235	01121
R68	RESISTOR, fixed composition 33K 1/2W 5%	R9-333	EB3335	01121
R69	RESISTOR, fixed composition 18K 1/2W 5%	R9-183	EB1835	01121
R70	RESISTOR, variable composition 1 Meg 1/2W 10%	V-104-1	V-104-1	02979
R71	RESISTOR, fixed composition 3.3Meg 1/2W 5%	R9-335	EB3355	01121
R81	RESISTOR, fixed composition 1K 10W 5%	R61-102	BROWN DEVIL	44655
R82	RESISTOR, fixed composition 680Ω 1/2W 10%	R10-681	EB6811	01121
R83	RESISTOR, fixed composition 220K 1/2W 10%	R10-224	EB2241	01121
R84	RESISTOR, fixed composition 27K 2W 10%	R17-273	HB2731	01121
R85	RESISTOR, fixed composition 4.7K 1/2W 10%	R10-472	EB4721	01121

Symbol No.	Description	CMC Part No.	Mfg. Part No.	Mfg. Code
R86	RESISTOR, fixed composition 2.2Meg 1/2W 10%	R10-225	EB2251	01121
R87	RESISTOR, fixed composition 330K 1/2W 10%	R10-334	EB3341	01121
R88	RESISTOR, variable composition 50K 1/2W 20%	V-103	V-103	02979
R89	RESISTOR, fixed composition 220K 1/2W 10%	R10-224	EB2241	01121
R90	RESISTOR, fixed composition 270Ω 1W 10%	R14-271	GB2711	01121
R91	RESISTOR, fixed wirewound 10K 5W 10%	R52-103	CS-5	91637
R92	RESISTOR, fixed composition 68K 1W 5%	R13-683	GB6835	01121
R93	RESISTOR, fixed composition 1.8 Meg 5%	R9-185	EB1855	01121
R94	RESISTOR, fixed composition 47K 1/2W 10%	R10-473	EB4731	01121
R95	RESISTOR, fixed composition 820K 1/2W 10%	R10-824	EB8241	01121
R96-R97	RESISTOR, fixed composition 330K 1/2W 10%	R10-334	EB3341	01121
R98	RESISTOR, fixed composition 100Ω 1/2W 10%	R10-101	EB1011	01121
R99	RESISTOR, fixed composition 560K 1/2W 10%	R10-564	EB5641	01121
R100	RESISTOR, fixed composition 1.8 Meg 1/2W 5%	R9-185	EB1855	01121
R101	RESISTOR, fixed composition 680K 1/2W 5%	R9-684	EB6845	01121
R102	RESISTOR, fixed composition 1 Meg 1/2W 5%	R9-105	EB1055	01121
R103-R105	RESISTOR, fixed composition 1.8 Meg 1/2W 5%	R9-185	EB1855	01121
R106	RESISTOR, fixed composition 1.5 Meg 1/2W 5%	R9-155	EB1555	01121
R107-R109	RESISTOR, fixed composition 1.8 Meg 1/2W 5%	R9-185	EB1855	01121
R110	RESISTOR, fixed composition 1.5 Meg 1/2W 5%	R9-155	EB1555	01121
R111-R113	RESISTOR, fixed composition 1.8 Meg 1/2W 5%	R9-185	EB1855	01121
R114	RESISTOR, fixed composition 1.5 Meg 1/2W 5%	R9-155	EB1555	01121
R115-R117	RESISTOR, fixed composition 1.8 Meg 1/2W 5%	R9-185	EB1855	01121
R118	RESISTOR, fixed composition 1.5 Meg 1/2W 5%	R9-155	EB1555	01121
R119-R121	RESISTOR, fixed composition 1.8 Meg 1/2W 5%	R9-185	EB1855	01121
R122	RESISTOR, fixed composition 1.5 Meg 1/2W 5%	R9-155	EB1555	01121
R123	RESISTOR, fixed composition 150K 1/2W 5%	R9-154	EB1545	01121
R124	RESISTOR, fixed composition 330K 1/2W 10%	R9-334	EB3345	01121
SW1	SWITCH, wafer	S-117	3242J	37942
SW2-SW3	SWITCH, SPST toggle	S-201	8280-K16	88026
SW4	SWITCH, DPST enclosed black button	S-255	913	82389
SW5	SWITCH, wafer	S-106	S-106	02979
SW6	SWITCH, SPST toggle	S-201	8280-K16	88026
SW7	SWITCH, DPST (Part of R1)			02979
SW8	SWITCH, SPST (Part of R50)			02979
T1	TRANSFORMER, power	X-100	X-100	02979
TB1	TIME BASE, crystal assembly	XD100A	XD100A	02979
V1-V2	TUBE, electron 5963	T1-11	5963	86684
V3	TUBE, electron 5915	T1-12	5915	86684
V4-V8	TUBE, electron 5963	T1-11	5963	86684
V9	TUBE, electron 2D21	T1-18	2D21	86684
V10	TUBE, electron 5Y3-GT	T1-15	5Y3-GT	86684
V11	TUBE, electron 6AV5-GA	T1-20	6AV5-GA	24455

Symbol No.	Description	CMC Part No.	Mfg. Part No.	Mfg. Code
V12	TUBE, electron 6AU6	T1-19	6AU6	86684
V13	TUBE, electron OA2	T1-14	OA2	86684
V14-V15	TUBE, electron 5963	T1-11	5963	86684
	DECADE COUNTING UNIT	100C	100C	02979
	DECADE COUNTING UNIT	120C	120C	02979

Note: pf = pico farad = 10^{-12} farad.

INSTRUCTION MANUAL

MODEL XD100A

PLUG-IN TIME BASE

SPECIFICATIONS

Output Frequencies:	100 kc 150 volts peak-to-peak (pin 3). 10 kc (pin 4), 1 kc (pin 5), 100 cps (pin 7) 40 volts peak pulse (negative direction), 100 cps (pin 10), 140 volts peak pulse (negative direction).
Standardization:	May be calibrated either by "zero beating" with standard frequency transmissions from the National Bureau of Standards, Station WWV, or by comparison with a 100 kc laboratory frequency standard. Range of adjustment is approximately ±8 cps.
Stability:	Short term: 1 part per million Long term: 5 parts per million
Output Load	Not less than .01 mfd in series with 47K.
Power Requirements:	+200V ±50V regulated 12 ma. nominal at +200V 6.3VAC and 3.1 amp nominal.
Construction:	Modular plug-in unit, 11 pin octal-type plug.
Dimensions:	3 1/8" W x 5 7/16" H x 5 3/8" D seated
Weight:	22 ounces
Tube Complement:	5 type 5963
Crystal:	100 kc series resonance with temperature regulated oven.

THEORY OF OPERATION

GENERAL

The XD100A Time Base is a crystal-controlled oscillator followed by a buffer amplifier and three frequency dividers. The time base provides output pulse at the rate of 100 kc, 10 kc, 1 kc and 100 cps. The time base is stabilized to 1 part per million short term and 5 parts per million long term.

THE CRYSTAL-CONTROLLED OSCILLATOR AND BUFFER

The oscillator V1 uses a twin-triode tube in a highly stabilized circuit employing feedback between the two tube cathodes. The quartz crystal Y1, which is inserted in the feedback loop, operates in series resonance thereby restricting feedback voltages from maintaining oscillation to very narrow limits around the crystal frequency of 100 kc. This type oscillator minimizes errors due to stray capacity, tube parameter variations, etc. When the crystal is housed in its temperature-controlled oven, short term stability of the oscillator is of the order of 1 part per million. Long term stability is approximately 5 parts per million

For extreme precision, the trimmer capacitor C1 may be used to vary the oscillator frequency over a limited range of about ±8 cycles per second. This allows extremely close calibration when the oscillator is "zero beat" against standard frequency broadcasts from the National Bureau of Standards Station WWV, Arlington, Virginia.

The Buffer Amplifier V2 is used principally to isolate the Crystal Oscillator V1 from the following frequency divider stages, preventing changes in loading from affecting the oscillator accuracy. This amplifier also blocks voltage pulses and spikes from the frequency dividers which could feed back into the oscillator circuit. As another feature, the Buffer Amplifier acts as a clipper or limiter and delivers an output of square-top waveform which is easily differentiated into sharp pulses for driving the frequency dividers.

THE FREQUENCY DIVIDERS

Three Frequency Divider stages V3, V4 and V5 successively divide the 100 kc signal pulses from the Crystal Oscillator and Buffer into 10 kc, 1 kc and 100 cps timing signal pulses. All three dividers are unistable or "one-shot" multivibrators, and except for components giving different time constants, the circuits and principles of operation are identical.

The circuit of a typical frequency divider is given in Figure 1(a) which shows it to be two triode amplifiers connected so the plate voltage output of triode A is fed to the control grid of triode B, and the plate voltage output of triode B, in turn, is applied back to the grid of triode A.

Since the control grid of triode B is connected to the positive high voltage supply through resistors R6 and R7 this grid is held at a positive potential allowing substantial current flow. This results in a relatively low plate potential for triode B which is applied through resistor R3 to the grid of triode A. The heavy plate current flow also maintains a high positive cathode potential for both tubes.

This combination of low grid potential and high cathode potential for triode A is more than adequate for cut off and no plate current flows through this tube. This particular condition of triode A being cut off and triode B conducting is a stable state which will remain indefinitely until the circuit is disturbed.

A positive input pulse arriving at the plate of triode A and grid of triode B through capacitors C1 and C2 will have no effect since the grid of triode B already is maintained at a positive potential. A negative pulse, however, tends to reduce the plate current in triode B. This results in an increase in positive voltage at the plate of triode B which is coupled through resistor R3 and capacitor C3 to the grid of triode A. Furthermore, the drop in plate current reduces the positive potential of both cathodes. Under these conditions triode A begins to conduct plate current, and the current flowing through resistor R1 causes a voltage drop which is coupled through capacitor C2 to the grid of triode B reducing the plate current in triode B still further. This results in an even greater positive signal to the grid of triode A, and so on.

The action, therefore, is accumulative and in a small fraction of a microsecond the conduction states of the two tubes are interchanged, triode A becoming conducting and triode B being cut off with a large negative charge accumulated on grid capacitor C2.

The two triodes remain in this state as long as a substantial negative charge is retained on capacitor C2. But this charge begins to leak off through resistors R6 and R7, and at some definite time later, as determined by the capacitor and resistor values, the negative grid bias for triode B decreases to the point at which plate current can flow. Once plate current is initiated in triode B a reverse switching action takes place to restore triode B to a conduction state and return triode A to the cut off condition. The circuit then will remain in this initial stable state until another negative input pulse is received.

How this time delay characteristic is used for frequency division is illustrated in Figures 1(b), 1(c) and 1(d). Pulses from the Buffer Amplifier in the cyrstal time base unit are shown in Figure 1(b). After differentiation in capacitor C1 of Figure 1(a) these 100 kc pulses appear as seen in Figure 1(c) and are used in this form to trigger the frequency divider.

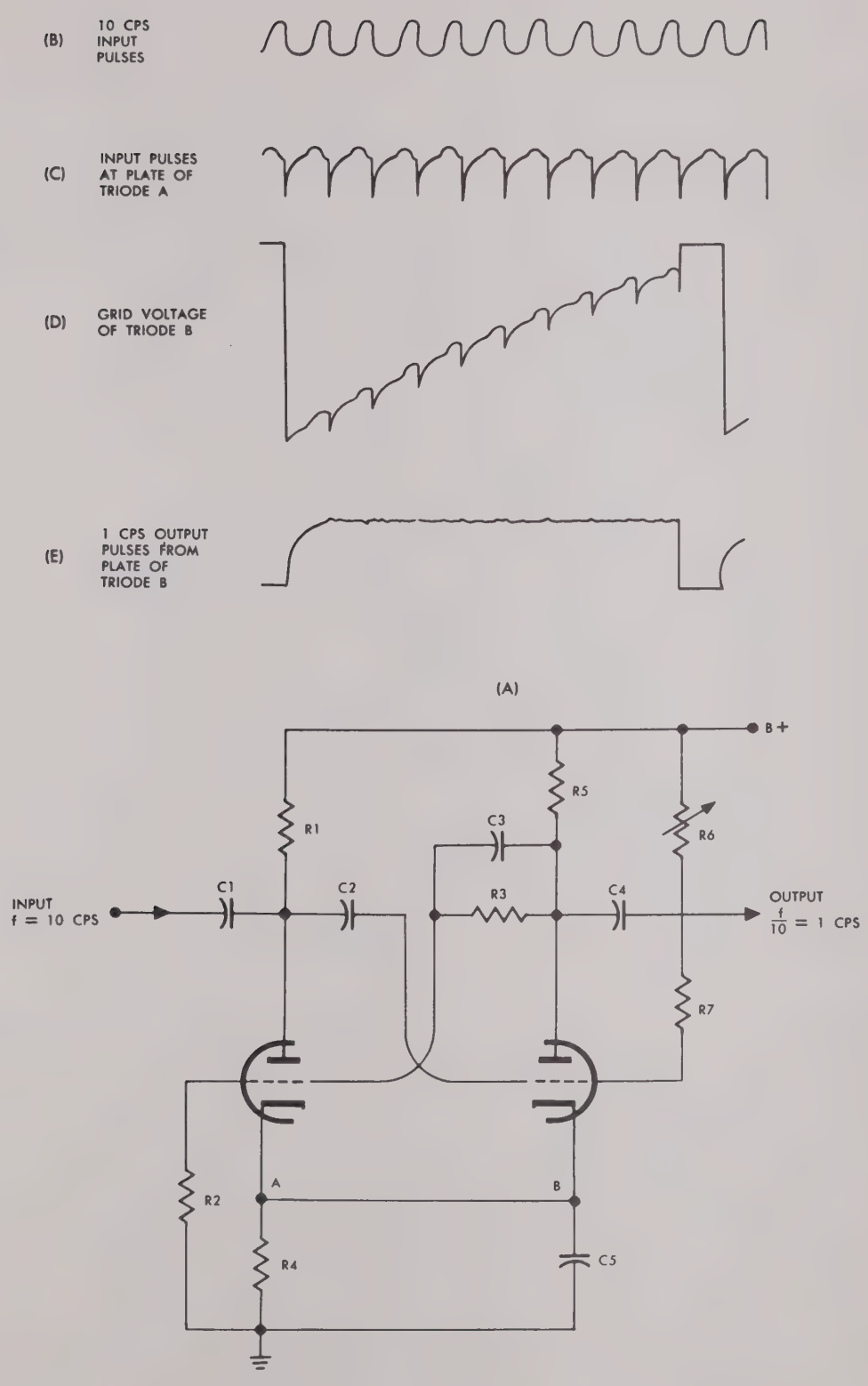
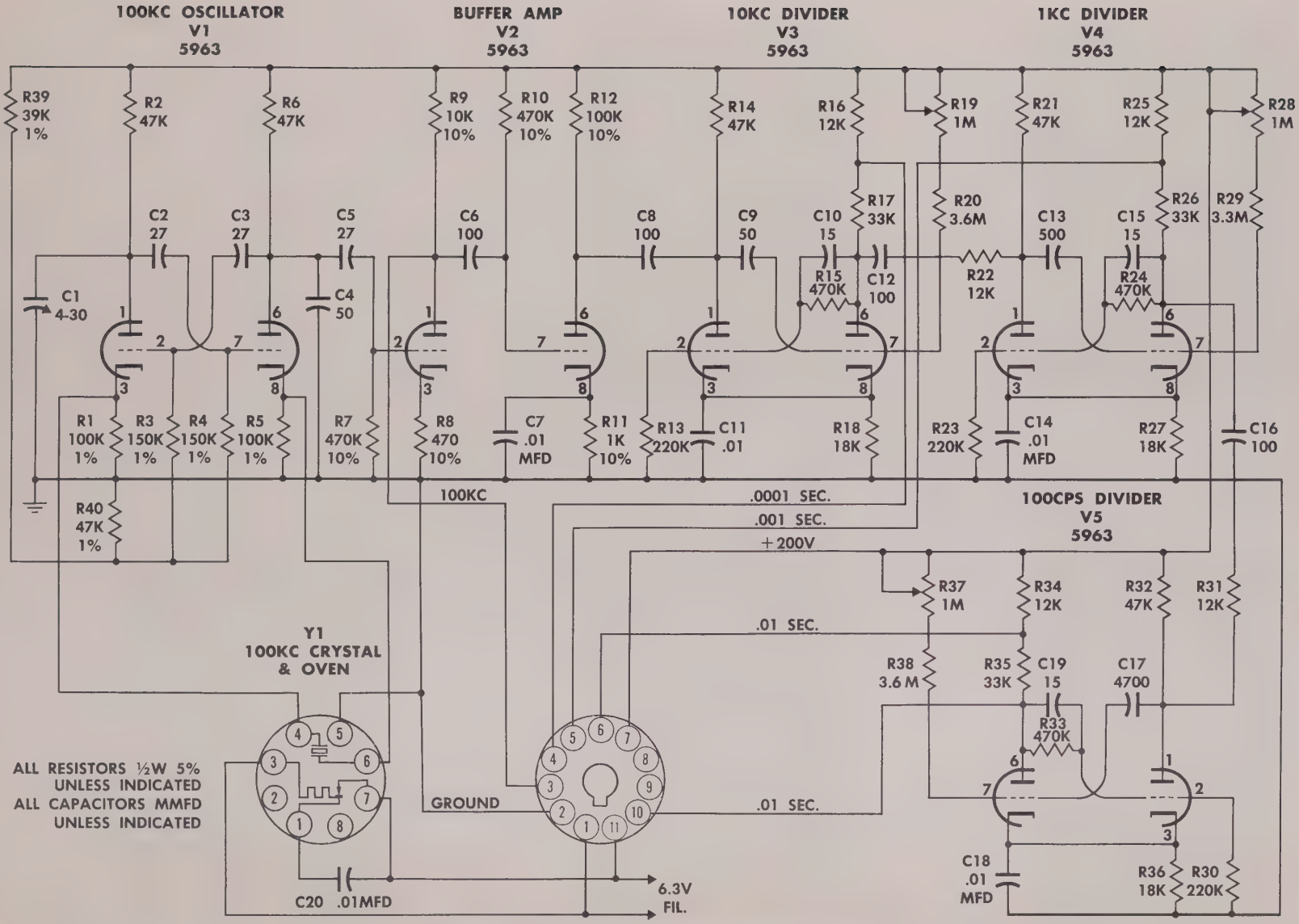
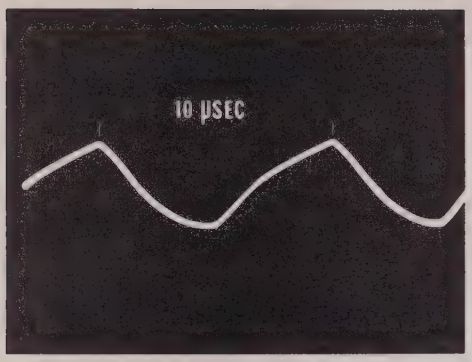


Figure 1. Typical Frequency Divider and Waveforms

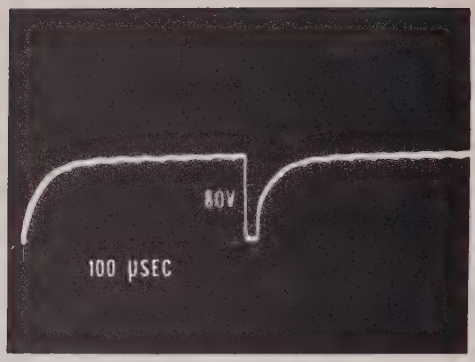


XD100-2A

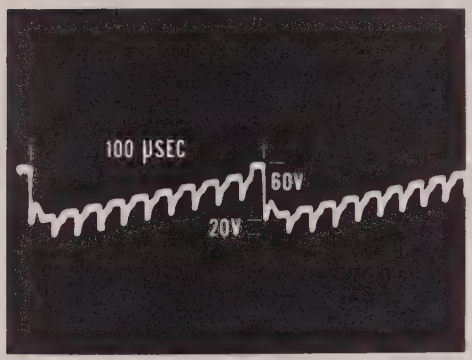
MODEL XD100A PLUG-IN TIME BASE



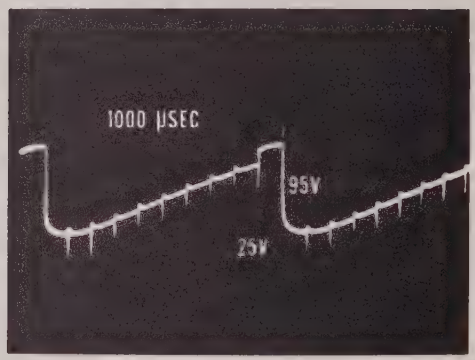
V1 PIN 6



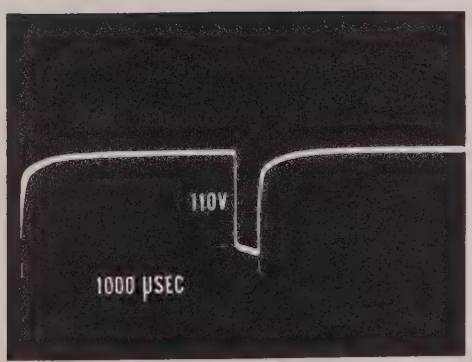
V3 PIN 6



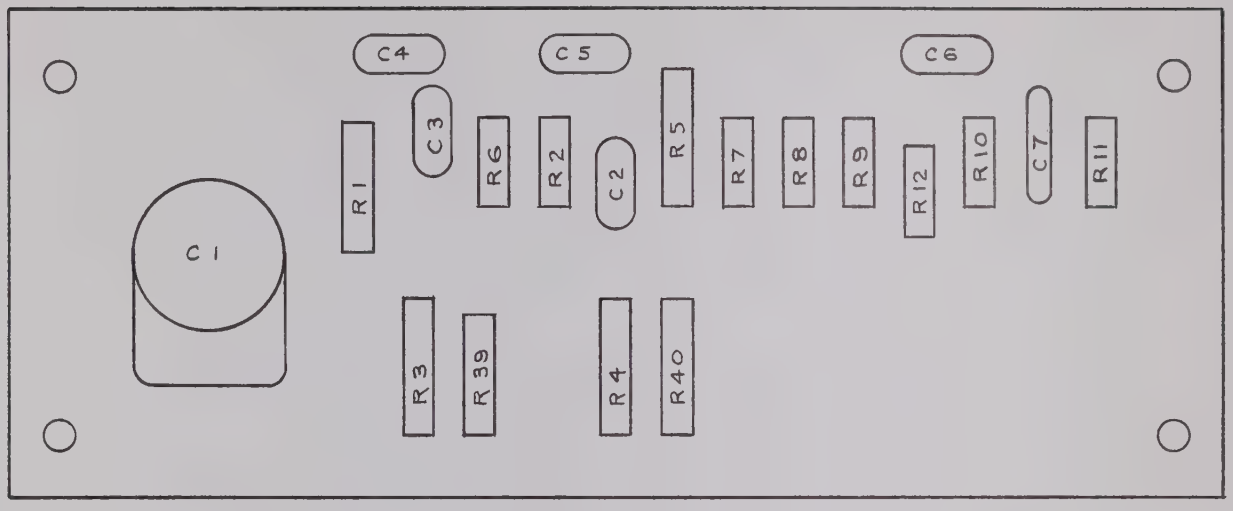
V3 PIN 7



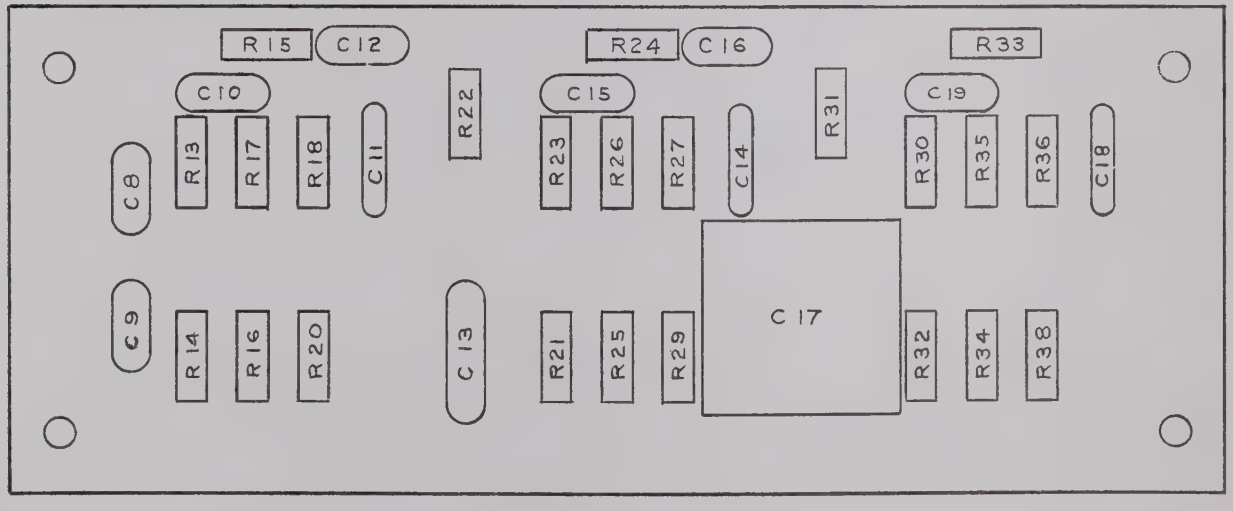
V4 PIN 7



V4 PIN 6



OSCILLATOR BOARD



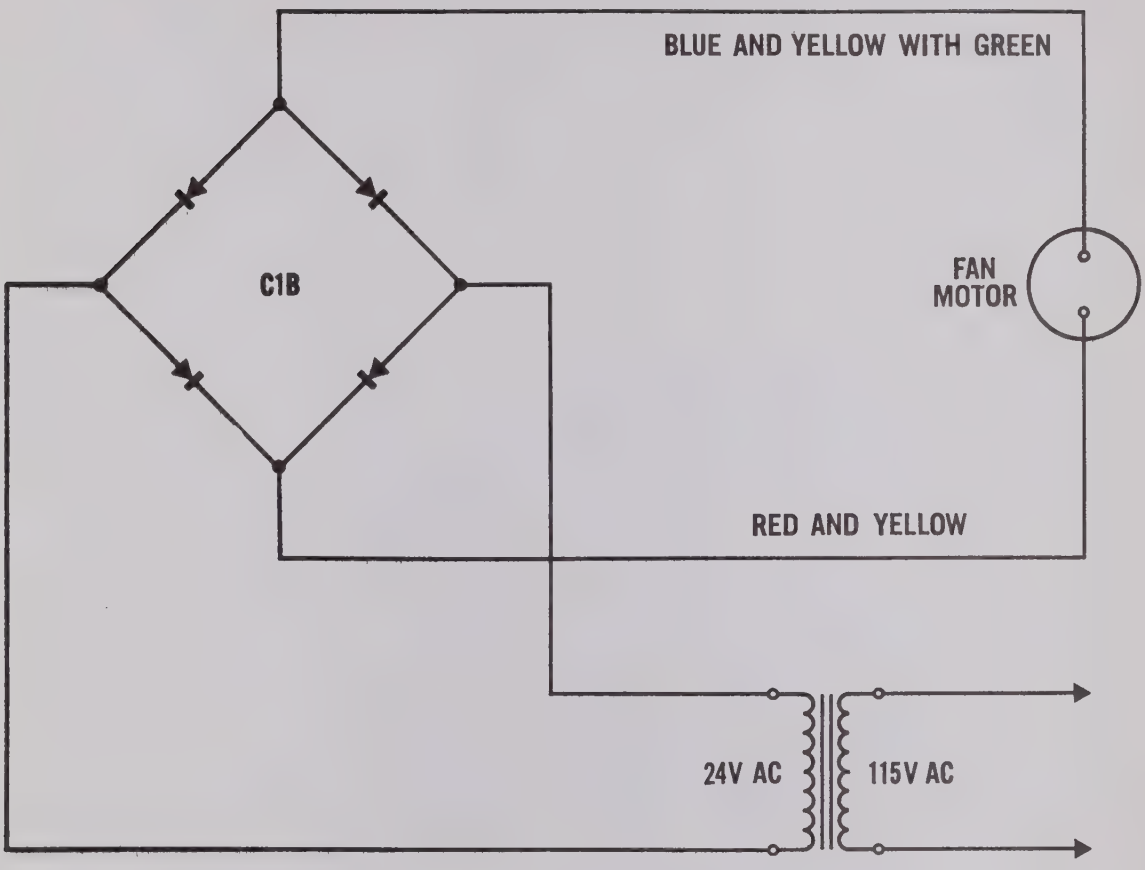
DIVIDER BOARD

XD100 CIRCUIT BOARD PARTS IDENTIFICATION

MODEL XD-100A

PARTS LIST

SYMBOL NO.	DESCRIPTION	CMC PART NO.
C1	CAPACITOR, variable 4-30 mmfd	4040100
C2,C3,C5	CAPACITOR, fixed mica 27 mmfd	4052270
C4 & C9	CAPACITOR, fixed mica 50 mmfd	4052500
C6,C8,C12,C16	CAPACITOR, fixed mica 100 mmfd	4052101
C7,C11,C14,C18,C20	CAPACITOR, fixed mica .01 mfd	4001103
C10,C15,C19	CAPACITOR, fixed mica 15 mmfd	4052150
C13	CAPACITOR, fixed mica 500 mmfd	4063501
C17	CAPACITOR, fixed 4700 mmfd	4022472
R1,R5	RESISTOR, fixed composition 100K 1/2w 1%	4630104
R2,R6,R14,R21,R32	RESISTOR, fixed composition 47K 1/2w 5%	4609473
R3,R4	RESISTOR, fixed composition 150K 1/2w 1%	4630154
R7,R10	RESISTOR, fixed composition 470K 1/2w 10%	4610474
R8	RESISTOR, fixed composition 470 1/2W 10%	4610471
R9	RESISTOR, fixed composition 10K 1/2W 10%	4610103
R11	RESISTOR, fixed composition 1K 1/2w 10%	4610102
R12	RESISTOR, fixed composition 100K 1/2w 10%	4610104
R13,R23,R30	RESISTOR, fixed composition 220K 1/2w 5%	4609224
R15,R24,R33	RESISTOR, fixed composition 470K 1/2w 5%	4609474
R16,R22,R25,R31,R34	RESISTOR, fixed composition 12K 1/2w 5%	4609123
R17,R26,R35	RESISTOR, fixed composition 33K 1/2w 5%	4609333
R18,R27,R36	RESISTOR, fixed composition 18K 1/2w 5%	4609183
R19,R28,R37	RESISTOR, variable 1 meg 1/2w 5%	5000104
R20,R38	RESISTOR, fixed composition 3.6 meg 1/2w 5%	4609365
R29	RESISTOR, fixed composition 3.3 meg 1/2w 5%	4609335
R39	RESISTOR, fixed composition 39K 1/2w 1%	4630393
R40	RESISTOR, fixed composition 47K 1/2w 1%	4630473
V1 through V5	TUBE, electron 5963	4901011
Y1	CRYSTAL WITH OVEN	4200001
	BRACKET, board (02-341)	1250341
	RING, tru-arc	4404002
	FRAME (03-333)	1260333
	SOCKET, 9 pin tube	4103097
	SOCKET, 8 pin tube	4103019
	PLUG, 11 pin	4107009
	BOARD, printed circuit (B116)	1290116
	BOARD, printed circuit (B253)	1290253
	BRACKET, pot (02-342)	1250342
	COVER (03-340)	1260340

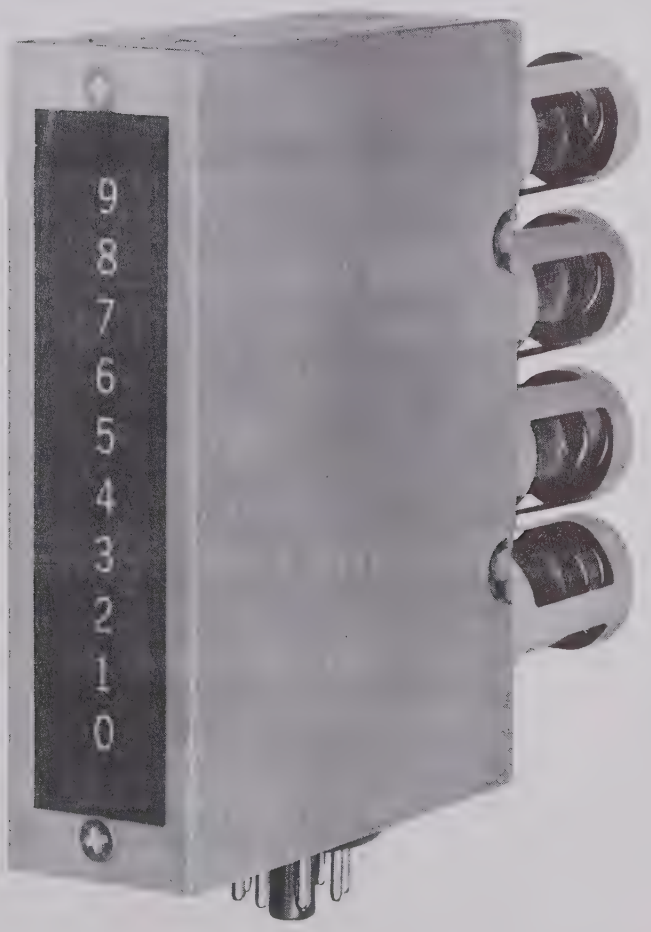


OPTION G
50-400 CPS POWER

INSTRUCTION MANUAL
MODEL 100, 105, 120, AND 125 SERIES
DECADE COUNTING UNIT

SERIAL NO. _____

MODIFICATIONS _____



COMPUTER MEASUREMENTS CO.

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SECTION I

INTRODUCTION

1-1 DESCRIPTION

The Computer Measurements Corporation Models 100, 105, 120 and 125 Decade Counting Units are versatile plug-in electronic counters. The 100 and 120 series counters count and display the number of electric pulses fed into its input. There is an illuminated vertical column of numbers from 0 to 9. The Model 100 series is capable of counting at rates up to 100,000 cps. The Model 120 series is capable of counting at rates up to 220,000 cps. The 105 and 125 series are identical to the 100 and 120 series respectively except the input count is not displayed.

For each pulse fed into the counting unit the lamp illuminated behind one number is extinguised and the lamp behind the next higher number turned on. If started at "0" the first pulse received would extinguish the "0" lamp and light the "1" lamp. The next pulse would illuminate the "2" lamp and extinguish the "1" lamp, etc. At the count of ten the figure "9" is extinguished and "0" illuminated again. This process is continually repeated as long as input pulses are supplied.

At the count of ten an output pulse is generated by the counting unit. This output pulse can be used to drive another counting unit in cascade. Each counting unit divides the input signals by 10 so that any desired significant figure can be displayed by cascading counting units. Two counting units will count to 99, three will count to 999, etc.

Printed circuitry is used extensively in the decade counting units to maintain rigid tolerances and produce a reliable, sturdy and stable counting unit. This method of manufacture minimizes stary circuit capacity and permits easy servicing, test and maintenance.

All models mount directly into a standard octal socket except the C models which mount into a standard 11-pin octal-type socket. Each decade is secured by a mounting screw either at the top or front of the unit.

1-2 DIFFERENCE AMONG MODELS

The 100 series operates at rates 0 to 100,000 cps and displays the count on an illuminated panel. The 105 series is identical to the 100 series except it does not display the count. The 120 series operates at rates from 0 to 220,000 cps and displays the count on an illuminated panel. The 125 series is identical to the 120 series except it does not display the count. The following chart illustrates the differences between the models within each series.

Model	Characteristic
A	Decade counting unit. Resets to zero with positive reset input, resets to nine with negative reset input.
B	Same as A with staircase (analog) output.
C	Same as A with 4-line 1-2-2'-4 code output.

CB	Same as A with 4-line 1-2-2'-4 code output and blanking.
CE	Binary counting unit with 4-line 1-2-4-8, 4-lamp read-out resets to zero with positive reset input, resets to 15 with negative reset input.
D	Decade counting unit. Resets to nine with positive reset input, resets to zero with negative reset input.
E	Binary counting unit, 4-lamp read-out, resets to zero with positive reset input, resets to 15 with negative reset input.
L	Operates on low voltage (150v dc).
N	Nixie read-out.

1-3 SPECIFICATIONS

1-3-1 MODEL 100 AND 105 SERIES

Count indication	Direct read-out, decimal numerals (100 series only)
Input requirements	Negative pulse, 70 volts peak with rise time and duration specified. Amplitude variable with rise time and duration.
Rise Time	1 microsecond
Duration	2 microseconds minimum
Resolution of paired pulses	5 microseconds
Reset to zero	Instantaneous by opening grid circuit, or by application of a 60 to 100 volt positive pulse.
Reset to nine	By application of a 60 to 100 volt negative pulse.
Maximum counting rate	In excess of 100,000 cps
Power Requirements	250 volts dc at 12 milliamperes nominal 6.3 volts ac at 1.2 amperes nominal.
Construction	Modular plug-in unit with octal-type socket
Dimensions	100: 1-3/8" x 5-1/2" x 5-1/2" overall 105: 1-1/2" x 5-1/2" x 4-5/8" overall
Weight	100: 14 ounces 105: 12 ounces
Tube complement	4 type 5963

1-3-2 MODEL 120 AND 125 SERIES

Count indication	Direct read-out, decimal numerals (120 series only)
Input requirements	Negative pulse, 70 volts peak with rise time and duration specified. Amplitude variable with rise time and duration.
Rise time	0.5 microsecond
Duration	1.5 microsecond minimum
Resolution of paired pulses	2.5 microseconds
Reset to zero	Instantaneous by opening grid circuit, or by application of a 60 to 100 volt positive pulse.
Reset to nine	By application of a 60 to 100 volt negative pulse.
Maximum counting rate	In excess of 200,000 cps
Power requirements	250 volts dc at 16 milliamperes nominal 6.3 volts ac at 1.2 amperes nominal
Construction	Modular plug-in unit with octal-type socket
Dimensions	120: 1-3/8" x 5-1/2" x 5-1/2" overall 125: 1-1/2" x 5-1/2" x 4-5/8" overall
Weight	120: 14 ounces 125: 12 ounces
Tube complement	4 type 5963

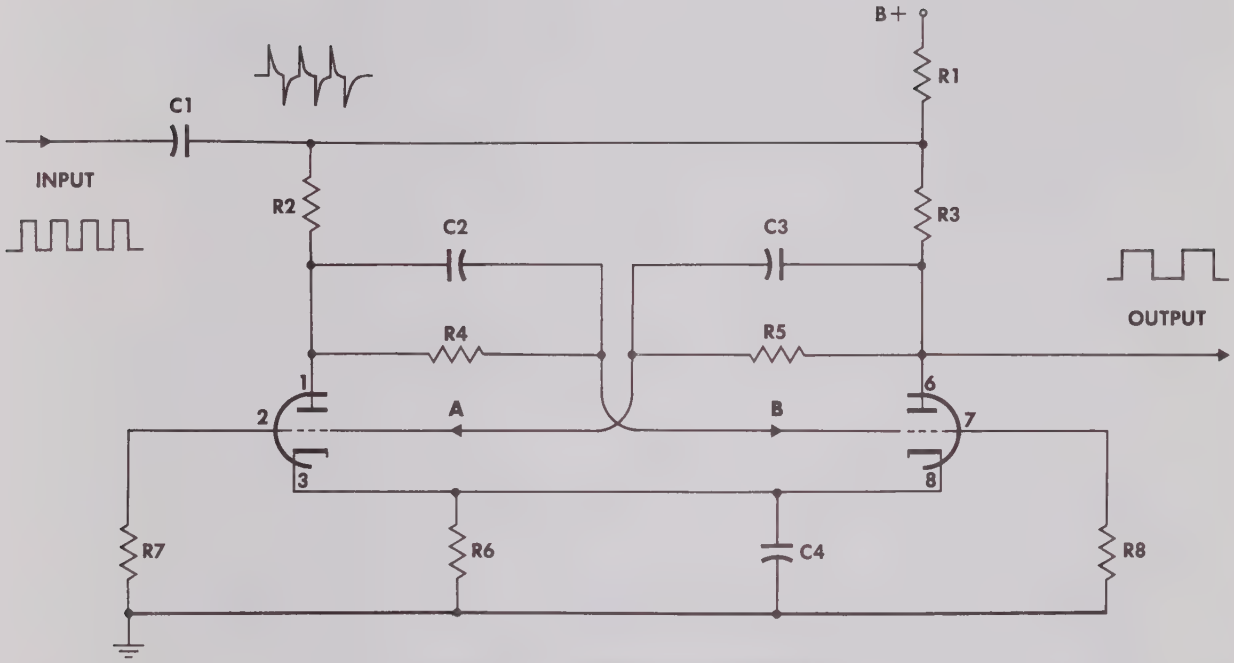


FIG. II-1 TYPICAL BINARY

102-3

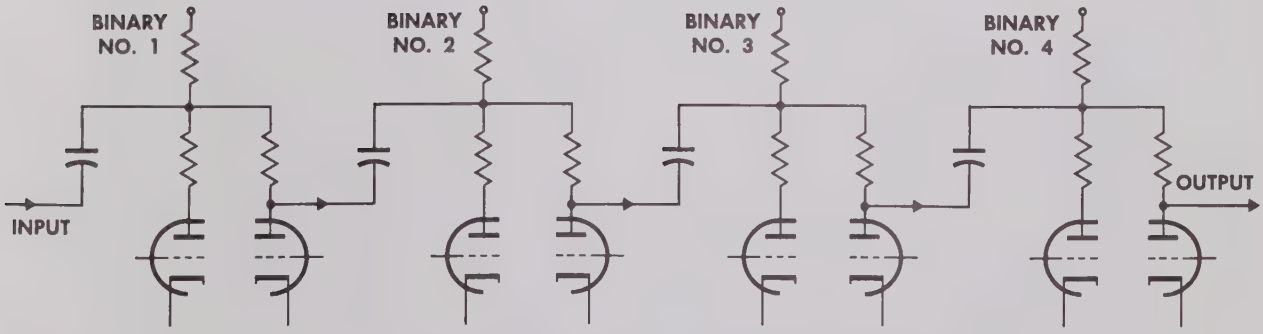


FIG. II-2 CASCADING BINARIES

102-4

SECTION II

THEORY OF OPERATION

2-1 GENERAL

The decade counting units consist of four cascaded binary stages. The binaries are permuted to operate with a scale of 10 rather than a scale of 16, for decade operation. The fourth binary supplies an output which may be used to drive additional counting units. In the 100 and 120 series a resistor matrix and 10 neon lamps are provided to illuminate a vertical numeral scale. This scale indicates the number of input pulses the units have counted.

2-2 BINARY OPERATION

The counting units utilize four twin-triode bi-stable multivibrators commonly referred to as binaries. The operation of all four binaries is essentially the same, therefore the theory of operation of only one binary will be described.

Figure II-1 illustrates the circuit of a typical binary stage. This circuit has two stable states: either stage A is conducting and stage B is cut-off, or stage B is conducting and stage A is cut-off. Assuming initially that stage A is conducting, the plate of stage A is at a relative low potential. This condition produces a low potential at the grid of stage B. The current through the common cathode resistor R6 and stage A produces a high bias voltage on the cathode of stage B. The low grid potential and high cathode potential of stage B biases it beyond cut-off. With stage B cut-off its plate is at a high potential. This condition produces a high potential at the grid of stage A and further insures the stability of this condition.

A square wave input, as illustrated in figure II-1, will flip the binary from its initial condition to the second condition with stage A cut-off and stage B conducting. Capacitor C1 and resistor R1 differentiate the square wave producing positive going and negative going spikes. The positive going spikes have no effect upon the binary but the negative going spikes readily initiate the characteristic triggering action.

The negative spike input drives the grids of both stages in a negative direction. Since stage B is already at cut-off, the increased negative grid signal has no effect. Stage A has a positive grid potential and the input decreases the plate current of stage A. Decreasing the plate current of stage A causes a positive bias, to be applied to the grid, a negative bias, applied to the cathode of stage B. This bias is sufficient to operate stage B and the action becomes accumulative. Plate voltage of stage B drops, resulting in a lower grid bias for stage A. Stage A decreases plate current still more and additional positive bias is supplied to Stage B. The changeover is extremely rapid, usually requiring only a fraction of a microsecond from the time the binary is triggered to the completion of the changeover. The binary is now in its second stable state and will remain in this condition until another trigger input is received, at which time another changeover takes place and the binary is in its initial condition.

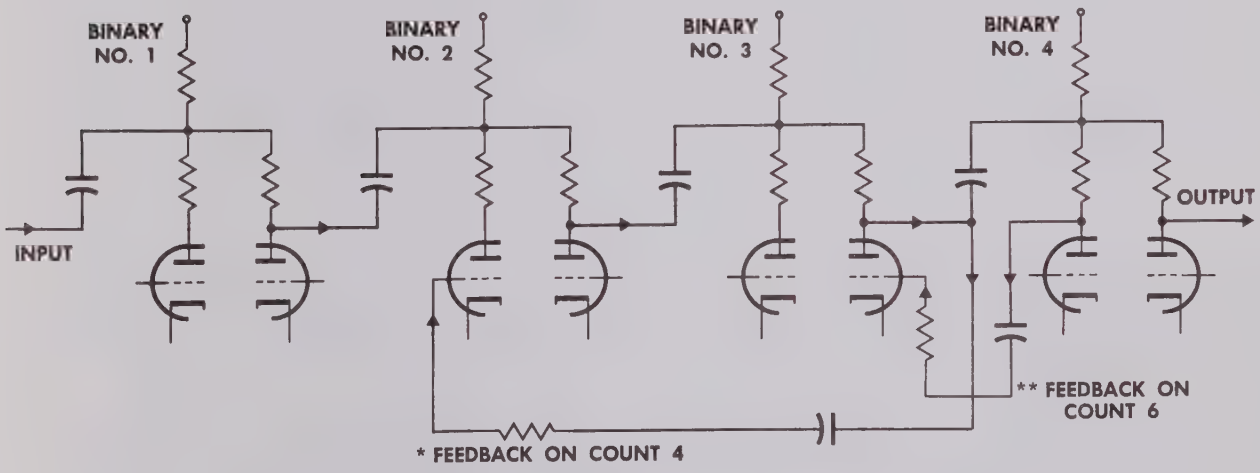
2-3 CASCADED BINARIES

The decade counting units require four binary stages. The binaries are connected in cascade (fig. II-2). Each binary produces an output pulse for every two input pulses, thus each binary divides by a factor of 2. Connected in cascade, four binaries will

produce an output pulse for every 16 input pulses, therefore counts from 0 to 15.

2-4 DECIMAL BINARIES

When decimal operation is desired, such as needed for frequency counters or period counters, the binaries may be permuted to the scale of 10, rather than the scale of 16, by feedback circuits. If six pulses are added internally every time ten input pulses are received the decade will effectively count from 0 to 9. Feedback circuits (fig. II-3) supply the extra pulses. On the count of 4 an extra pulse is fed from the third binary to the second. This feedback pulse flips the second binary into the alternate conduction state. In doing so the second binary is forced into the condition normal for the counting unit having received two additional external input pulses. In a similar manner, on the count of 6, a feedback pulse from the fourth binary is supplied to the third binary providing the condition normal for the counting unit, having received four additional external input pulses. These additional counts of 4 plus 2 provide the 6 counts necessary for the counting cycle, after receiving 10 external input pulses. Figure II-4 illustrates the firing order of four permuted binaries.



102-5

FIG. II-3 DECIMAL BINARIES

2-5 COUNT INDICATION

A complete Model 100 Series and Model 120 Series Decade Counting Unit is comprised of four binaries with two internal feedback loops, a resistor matrix and ten neon lamps which illuminate the numeral scale. The 105 and 125 Series Decade Counting Units do not contain the resistor matrix and neon lamps to indicate the count. For the 100 and 120 series counting units to indicate the counts received, it is necessary to sense the conducting and the nonconducting stages of all four binaries and use this data to

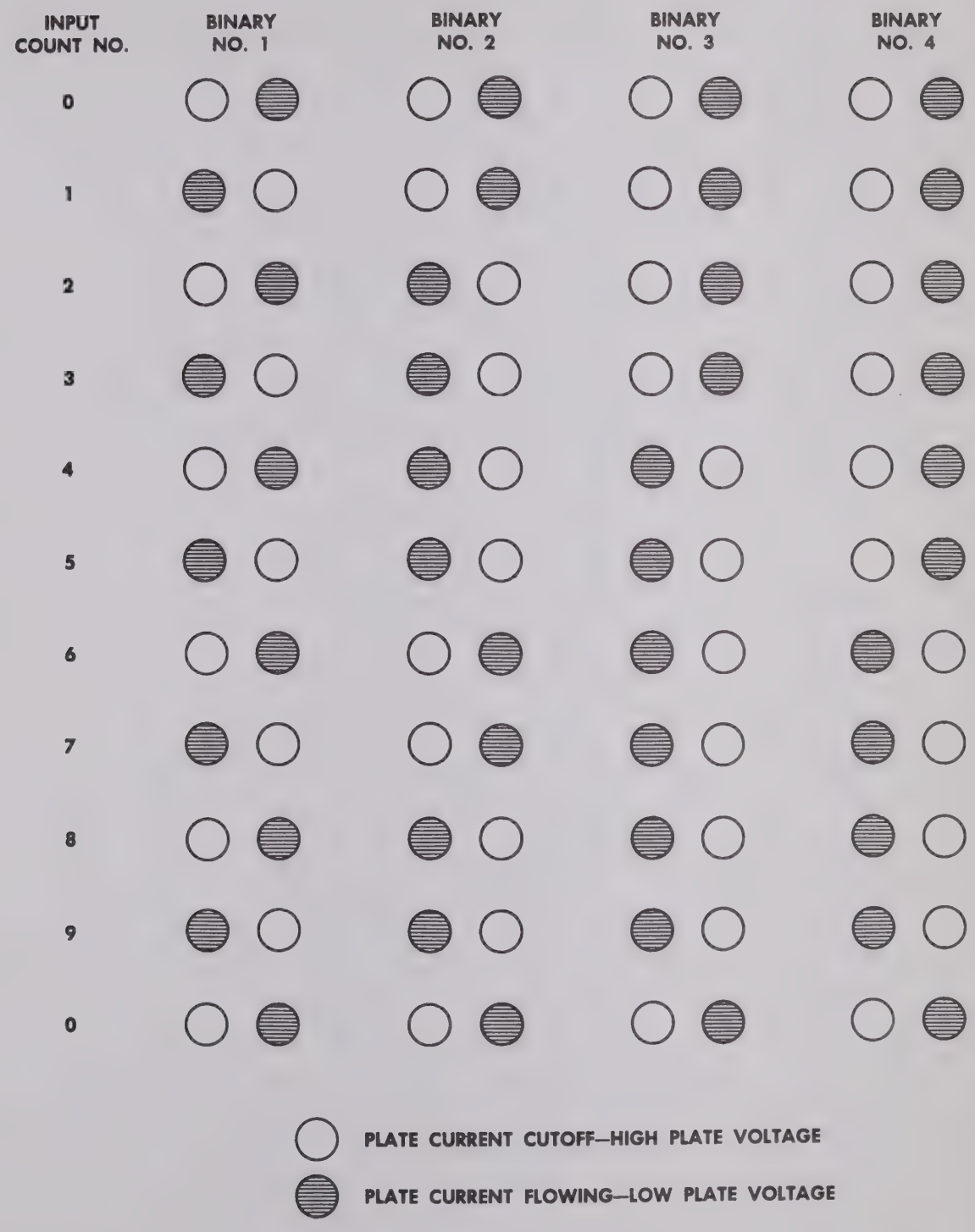


FIG. II-4 FIRING ORDER OF FOUR PERMUTED BINARIES

illuminate the appropriate neon lamp. The resistor matrix and neon lamps are used to sample and display the count indication. Figure II-5 illustrates how the resistor matrix and lamps are connected to the four binaries to fire the appropriate neon lamp.

For any one count, the conducting and non-conducting condition of the first binary is determined by the count being odd or even. One terminal of each of the even lamps is connected to the even bus wire which is connected through a resistor to one plate of the first binary. Likewise, one terminal of each odd lamp is tied to the odd bus which is connected through another resistor to the second plate of the first binary. As the first binary is continually switched back and forth by the input pulses, first the even bus supplies a relatively high voltage to one terminal of all the even lamps, then the odd bus supplies a relatively high voltage to all the odd lamps. This cycle repeats as long as input pulses are supplied to the decade.

Voltage is supplied to the remaining terminal of each lamp, by combinations of voltages from pairs of plates in the remaining three binaries through isolating resistors. Three possible voltages exist: a relatively high voltage when both plates are cut off; a medium voltage when one plate is cut off and one plate conducting; a relatively low voltage when both plates are conducting. Only the lamp with a relatively high voltage supplied to one terminal by either the odd or even bus and a relatively low voltage supplied to the second terminal will fire. Voltage never entirely disappears from across any of the neon lamps, but only one lamp receives sufficient voltage difference on its terminals to ionize.

As input pulses arrive, the first binary alternately switches a high potential between the odd and even buses. When the odd bus is supplied the high voltage, the odd lamp which is supplied the lowest voltage on the second terminal will fire. Similarly, when the even bus is supplied the high voltage, the even lamp which is supplied the lowest voltage on the second terminal will fire.

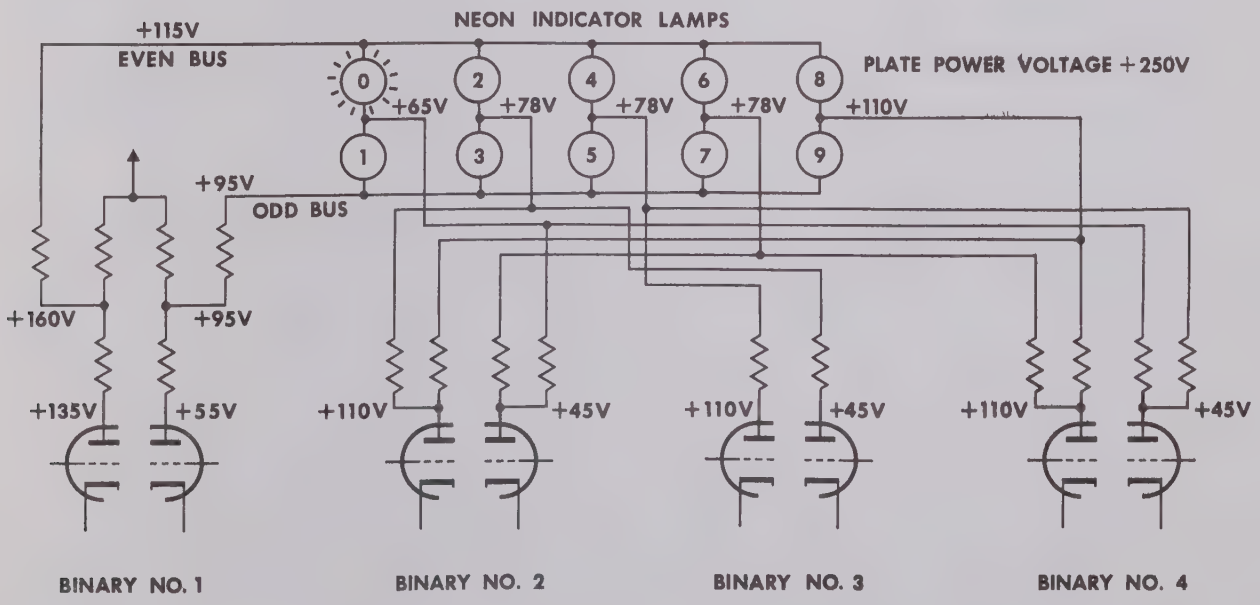


FIG. II-5
NEON LAMP RESISTOR MATRIX

102-15

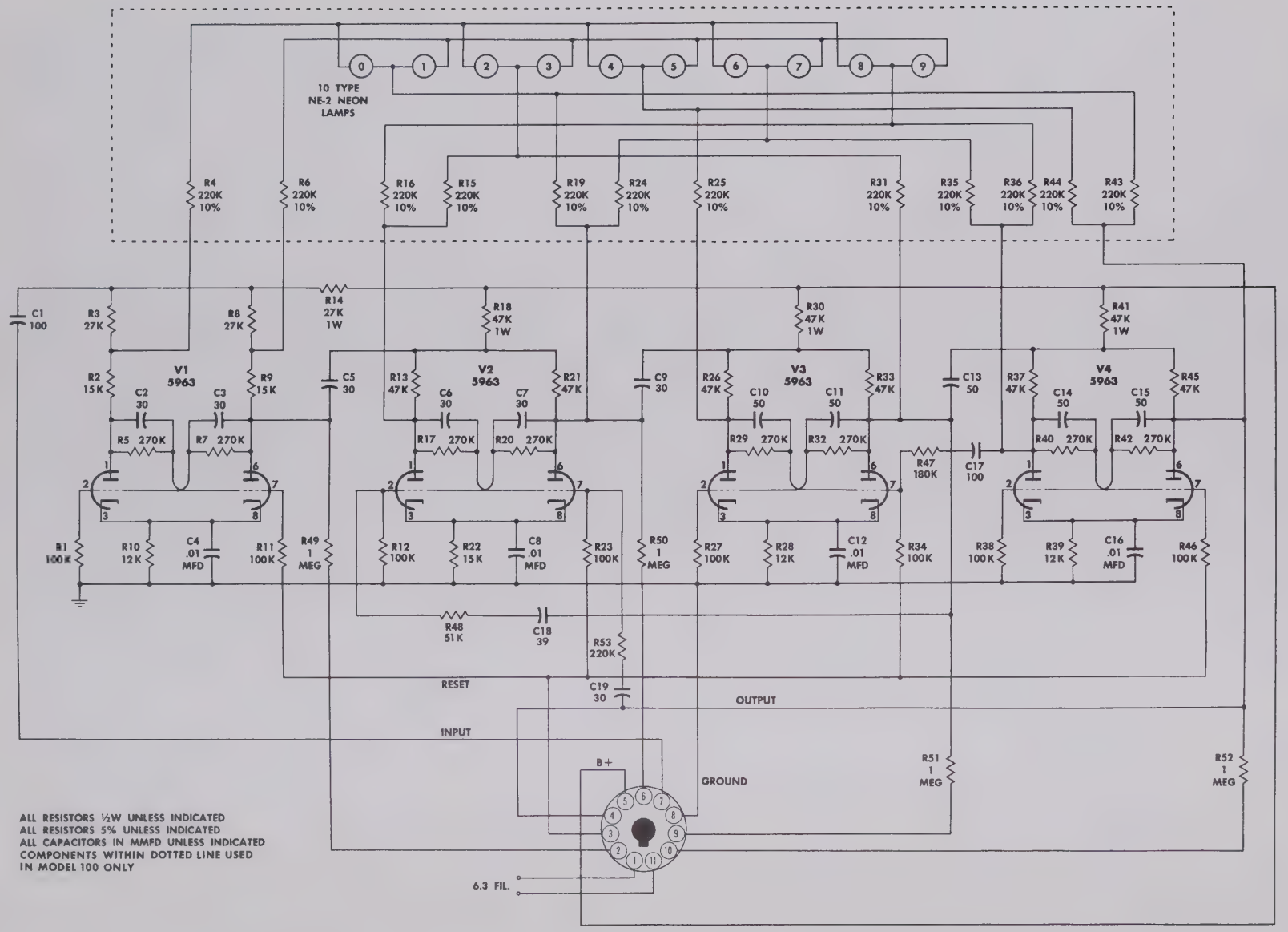


FIG. II-6 MODEL 100C AND 105C DECADE COUNTING UNIT

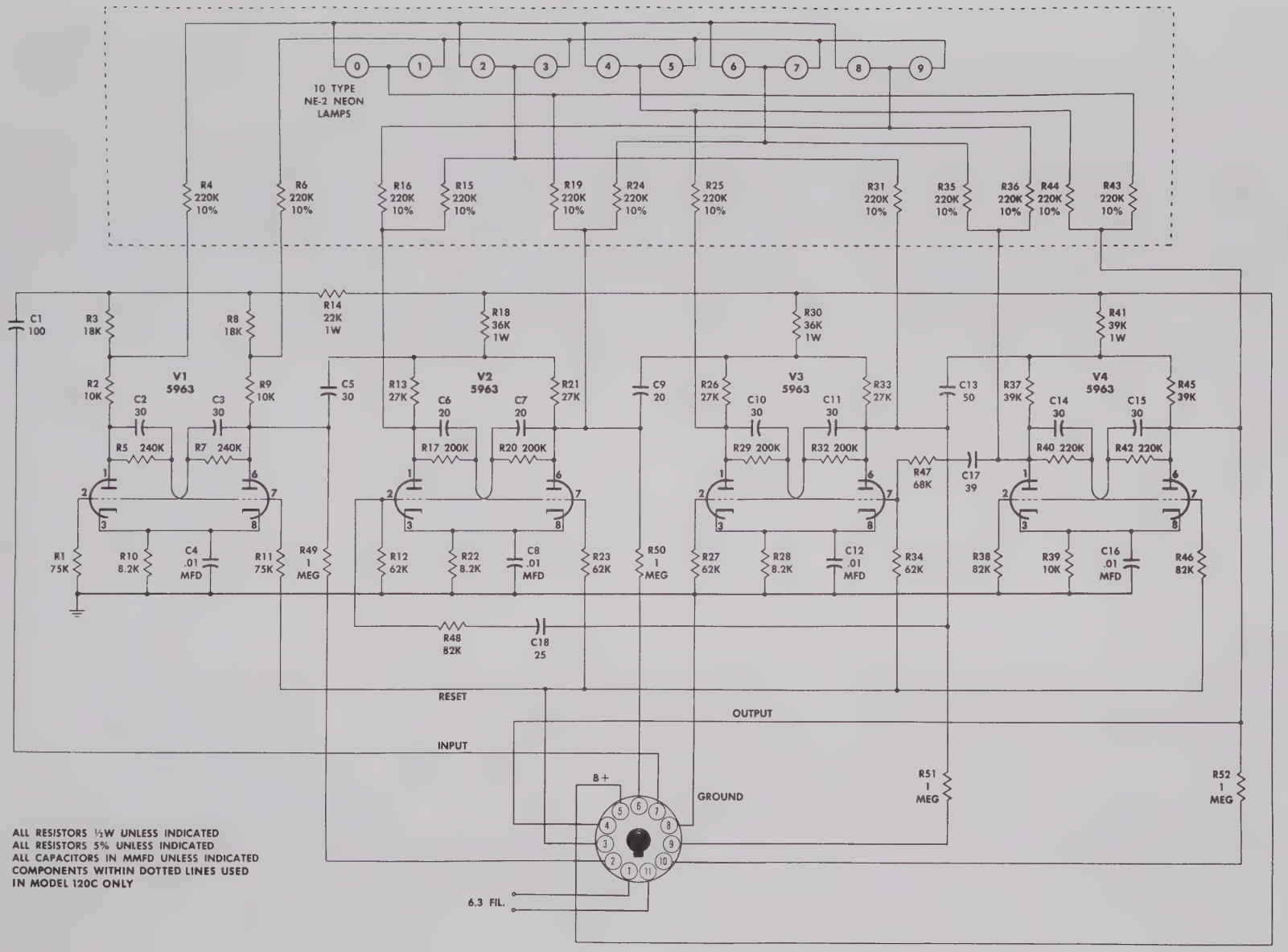


FIG. II-7 MODEL 120C AND 125C DECADE COUNTING UNIT

SECTION III

MAINTENANCE

3-1 GENERAL

This section lists some of the common trouble causes for associated external equipment, common trouble caused by the counting unit's internal circuitry and methods of checking the counting units. Because of the printed circuit wiring, the quality components used and the circuit design, the decade counting units require a minimum of maintenance and trouble-shooting. Maintenance may be required from time to time, however, if components fail or the unit is damaged. Whenever a counting unit gives an indication of false or incorrect counting, determine whether the counting unit or the associated equipment is at fault. This may be determined easiest by interchanging the suspected faulty counting unit with one known to be functioning correctly.

3-2 EXTERNAL TROUBLE

Generally, most external sources of trouble can be traced to power supply failure, improper input pulses or stray input pulses. Indications and symptoms of these are as follows:

Failure to count:	Insufficient power supply voltage, filament voltage failure, insufficient input pulse amplitude, incorrect polarity of input pulses, open reset line.
Spurious counting:	Stray pulses received, stray pulses from the power supply, noise from power line when equipment is not grounded.
Erratic counting:	Double pulses in input, imput pulses of insufficient or excess amplitude, input pulses of incorrect rise time, power supply voltage variations.
Failure to reset:	Grounded or shorted reset line, stray pulses from reset or associated circuitry.

3-3 INTERNAL TROUBLE

The majority of failures within the decade counting units are caused by defective or weak tubes. Tubes are best checked by replacing them, one at a time, with known good tubes, observing the counting behavior after each replacement. Tubes which have no effect upon counting performances may be restored to their former positions.

Defective components usually can be found by making a systematic voltage and resistance check at each of the binary tube sockets. Figure III-2 identifies and locates the components of the counting unit. Figures III-3 and III-4 list the voltage and resistance data. Use only a vacuum tube voltmeter in checking the counting unit. Care must be taken that pin 2 on the counting unit plug is left open to prevent unstable measurements because of the counting unit cycling.

3-4 LOW SPEED CHECKING

Setting up the decade with the proper power requirements and intermittently feeding single input pulses into it will often give aid in determining the particular stage in which trouble is located. Figure III-1 shows a simple circuit which will supply acceptable input pulses for low speed checking. When malfunctioning, a counting unit may have many stable states of various values such as two, four, six, eight, twelve or sixteen. The number of stable states indicates the various combination in which the lamps may light in sequence or in combination before the pattern begins to repeat. Some of the most probably abnormal counting sequences which may occur and their most probable source of trouble are as follows:

Failure to count, resets to 0 or 1	Defective first stage.
Two stable states, resets to 2; counts 2,3	Defective second or fourth stage.
Two stable states, resets to 4; counts 4,5	Defective second or third stage, no signal to second stage.
Four stable states, resets to 0; counts 0,1,8,9 or 6,7,8,9	Defective third stage, no signal to third stage.
Five stable states, resets to 0; counts 0,2,4,6,8	Defective first stage.
Six stable states, resets to 0; counts 0,1,2,3,4,5	Output overloaded or grounded, defective fourth stage, no signal to fourth stage.
Eight stable states, resets to 0; two lamps light simultaneously	Defective third stage.
Ten stable states, resets to 0; two lamps light simultaneously	Defective neon lamp.
Twelve stable states, resets to 0; counts 0,1,2,3,4,5,4,5,6,7,8,9	Defective feedback loop between third and fourth stages.
Twelve stable states, resets to 0; counts 0,1,2,3,4,5,4,5,6,7, 8 & 2, 9 & 3, 8,9	Defective feedback loop between third and fourth stages.
Sixteen stable states, resets to 0; counts 0,1,2,3,4,5,4,5,6,7, 8 & 2, 9 & 3, 6,7,8,9	Both feedback loops defective.

3-5 HIGH SPEED CHECKING

Low speed checking is extremely useful in locating defective components usually resulting in complete trouble-shooting and repair of the 100 and 120 Series Decade Counting Units. The 105 and 125 series, not having an illuminated scale, and in some cases the 100 and 120 series, may require high speed checking. A counter may, in some cases, operate satisfactorily at low speeds and fail at high speeds. In such instances, it is necessary to feed high-frequency square waves or pulses into the counting unit and check the performance with an oscilloscope.

Voltage waveforms present at the plates of each binary, while counting, are indicative of the behavior of each stage and will quickly show any malfunction.

Waveform inspection should be done by starting at the first binary stage and proceeding through the second, third and fourth stages in direct order. Any binary stage showing a pronounced discrepancy in plate voltage waveform probably will contain the faulty circuit or have a faulty feedback loop.

Normal waveforms which can be expected will vary greatly with the frequency of the input signals. In figure III-5 waveforms are shown for three input frequencies. With a test signal frequency of 10kc or lower the waveforms are relatively clean and sharp. When the test signal frequency approaches 100kc in the 100 and 105 series, and 200kc in the 120 and 125 series, the effects of stray distributed capacity become apparent as the waveform spikes broaden out and the pattern begins to "smear". This deterioration is quite normal and its progression leads to the maximum count, frequencies in excess of 100kc or 200kc, above which accurate counting is not possible.

Should the counting unit give indication of failing to count correctly at any given frequency, a convenient method of testing is to set the test input signal frequency just below the critical frequency and observe the waveforms of all four binaries. The test signal frequency should then be raised just above the critical frequency where malfunctioning begins and the waveforms examined again. Any abrupt change of waveform for any binary will be of help in locating the faulty stage.

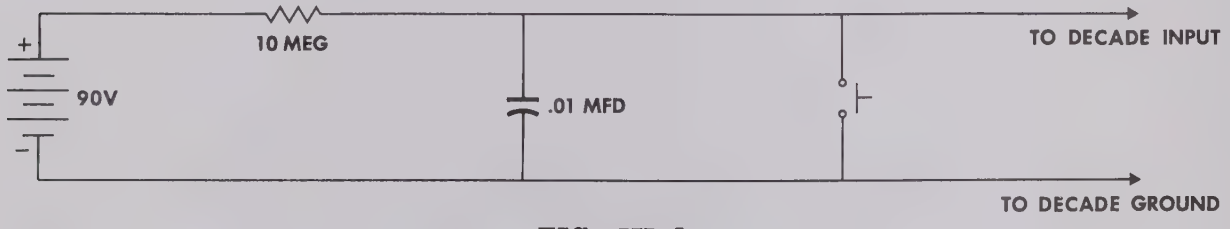
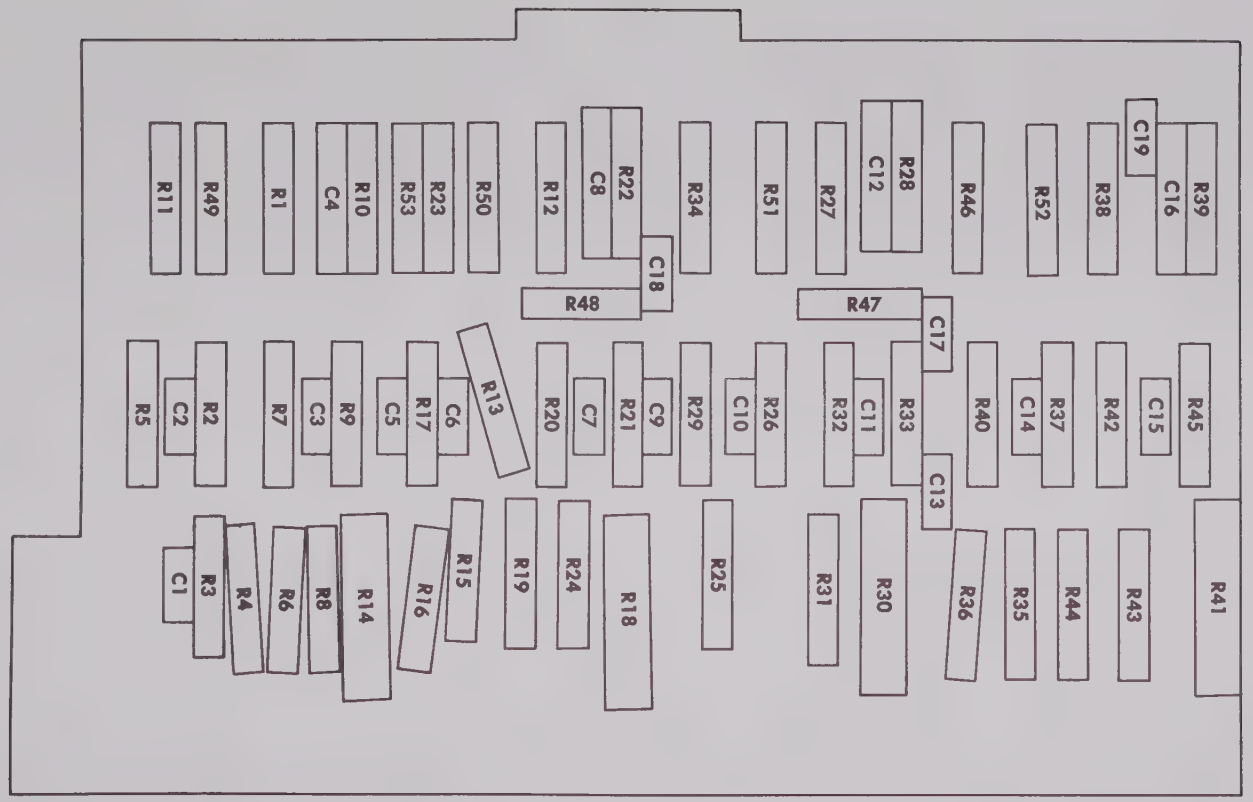


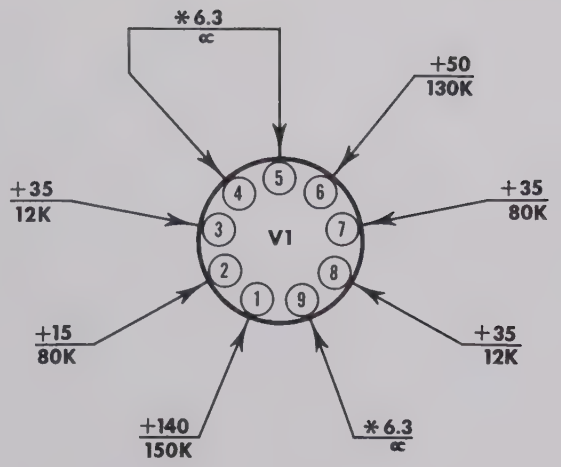
FIG. III-1

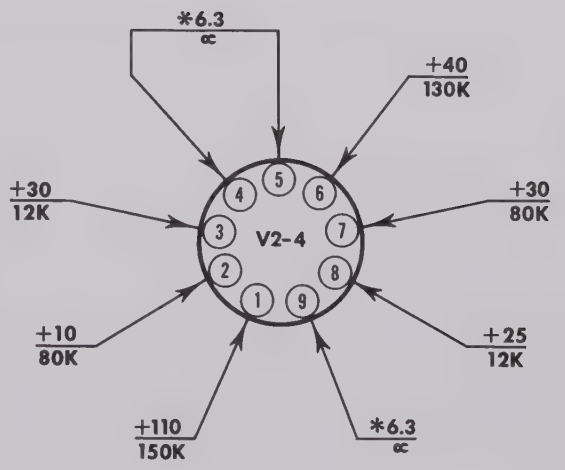
NEGATIVE INPUT PULSE GENERATOR FOR LOW-SPEED CHECKING

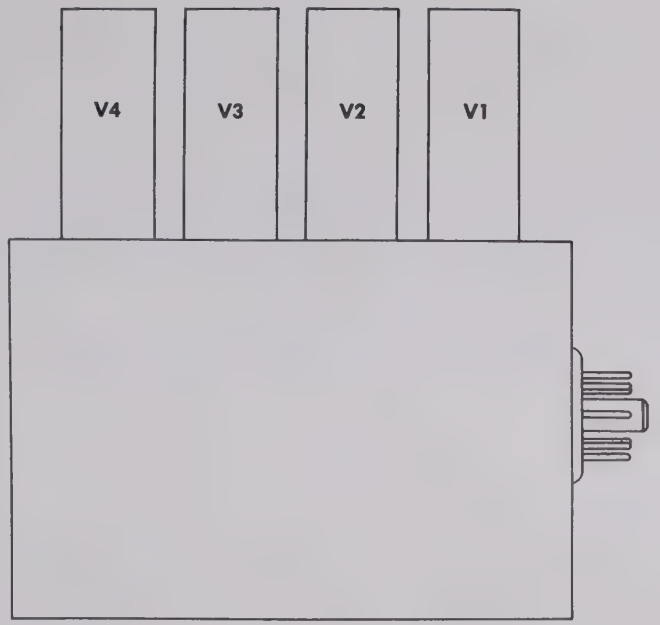
102-16



100-6B **FIG. III-2 PARTS IDENTIFICATION, MODEL 100C, 105C, 120C AND 125C**



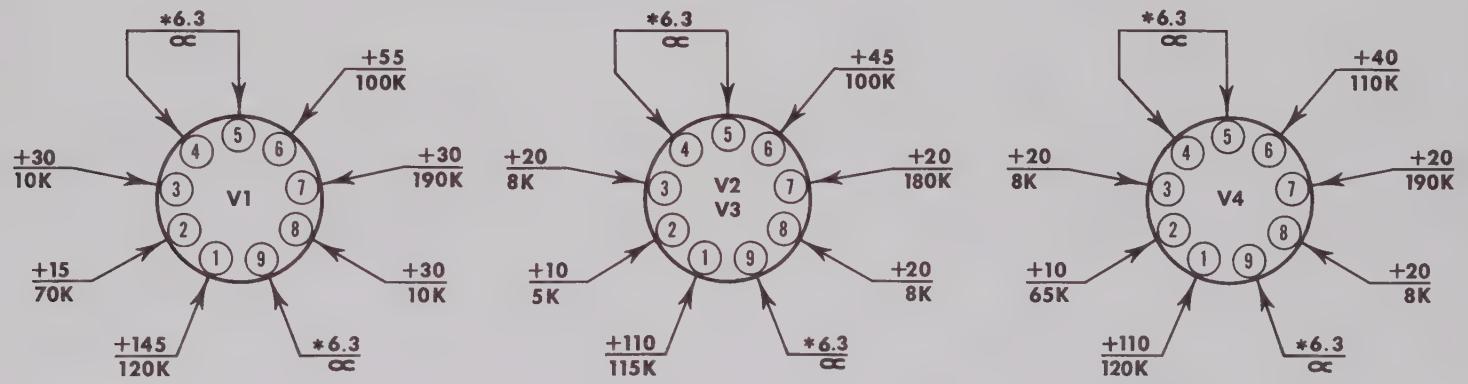


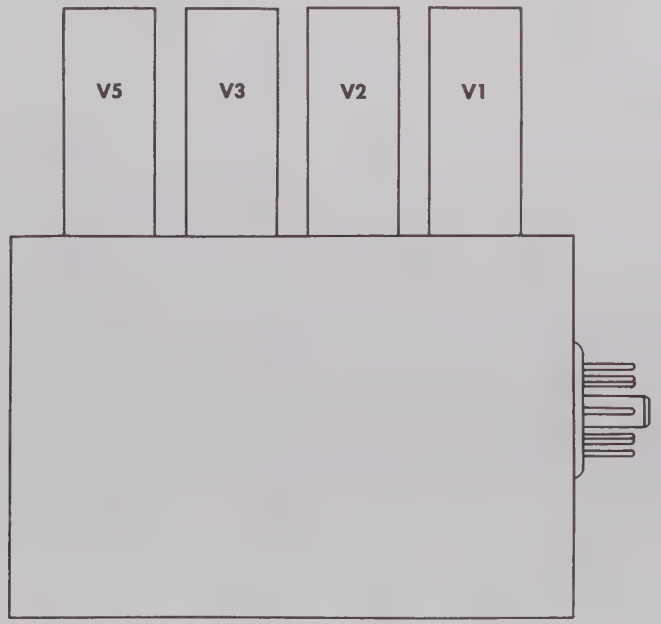


NOTES:

1. TUBE SOCKET POSITIONS ARE AS VIEWED FROM UNDERSIDE OF CHASSIS. DC VOLTAGES ARE PRECEDED WITH A "+" OR "−" SIGN AND APPEAR ABOVE THE LINE. RESISTANCES ARE SHOWN BELOW THE LINE. WHEN FOLLOWED BY K, THE VALUE IS IN THOUSANDS OF OHMS. WHEN FOLLOWED BY MEG, THE VALUE IS IN MILLIONS OF OHMS. WHEN NOTHING FOLLOWS, THE VALUE IS IN OHMS. AC VOLTAGES ARE DESIGNATED BY AN ASTERISK (*).
2. ALL DC VOLTAGES AND RESISTANCE MEASUREMENTS ARE MEASURED WITH RESPECT TO CIRCUIT GROUND. FILAMENT VOLTAGES ARE MEASURED FROM PIN TO PIN.
3. ALL MEASUREMENTS TAKEN WITH AN ELECTRONIC VOLTMETER.
4. ALL VOLTAGES AND RESISTANCE MEASUREMENTS ARE SUBJECT TO VARIATIONS DUE TO ACCURACY OF METERS USED AND TOLERANCE OF CIRCUIT COMPONENTS.
5. ALL VOLTAGE MEASUREMENTS TAKEN WITH UNIT RESET TO ZERO, AND B+ OF +250 VOLTS. RESISTANCE MEASUREMENTS WITH INPUT AND OUTPUT CONNECTIONS DISCONNECTED.

FIG. III-3 VOLTAGE AND RESISTANCE CHART, MODEL 100C AND 105C





NOTES:

1. TUBE SOCKET POSITIONS ARE AS VIEWED FROM UNDERSIDE OF CHASSIS. DC VOLTAGES ARE PRECEDED WITH A "+" OR "—" SIGN AND APPEAR ABOVE THE LINE. RESISTANCES ARE SHOWN BELOW THE LINE. WHEN FOLLOWED BY K, THE VALUE IS IN THOUSANDS OF OHMS. WHEN FOLLOWED BY MEG, THE VALUE IS IN MILLIONS OF OHMS. WHEN NOTHING FOLLOWS, THE VALUE IS IN OHMS. AC VOLTAGES ARE DESIGNATED BY AN ASTERISK (*).
2. ALL DC VOLTAGES AND RESISTANCE MEASUREMENTS ARE MEASURED WITH RESPECT TO CIRCUIT GROUND. FILAMENT VOLTAGES ARE MEASURED FROM PIN TO PIN.
3. ALL MEASUREMENTS TAKEN WITH AN ELECTRONIC VOLTMETER.
4. ALL VOLTAGES AND RESISTANCE MEASUREMENTS ARE SUBJECT TO VARIATIONS DUE TO ACCURACY OF METERS USED AND TOLERANCE OF CIRCUIT COMPONENTS.
5. ALL VOLTAGE MEASUREMENTS TAKEN WITH UNIT RESET TO ZERO, AND B+ OF +250 VOLTS. RESISTANCE MEASUREMENTS WITH INPUT AND OUTPUT CONNECTIONS DISCONNECTED.

120-6A

FIG. III-4 VOLTAGE AND RESISTANCE CHART, MODEL 120C AND 125C

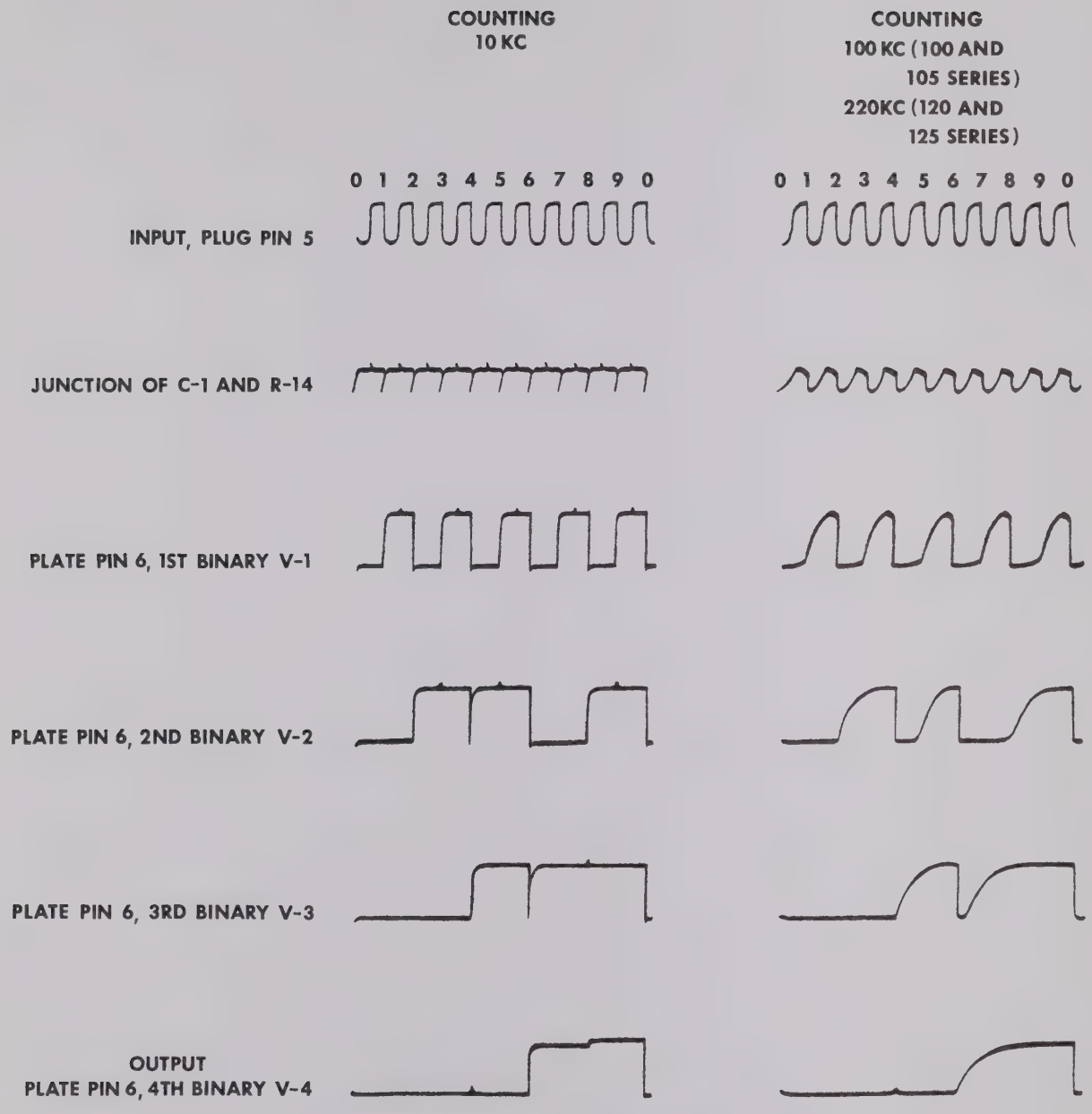

COUNTING
10 KC
COUNTING
100 KC (100 AND
105 SERIES)
220KC (120 AND
125 SERIES)
0 1 2 3 4 5 6 7 8 9 0
0 1 2 3 4 5 6 7 8 9 0
INPUT, PLUG PIN 5
JUNCTION OF C-1 AND R-14
PLATE PIN 6, 1ST BINARY V-1
PLATE PIN 6, 2ND BINARY V-2
PLATE PIN 6, 3RD BINARY V-3
OUTPUT
PLATE PIN 6, 4TH BINARY V-4

FIG. III-5 WAVEFORMS

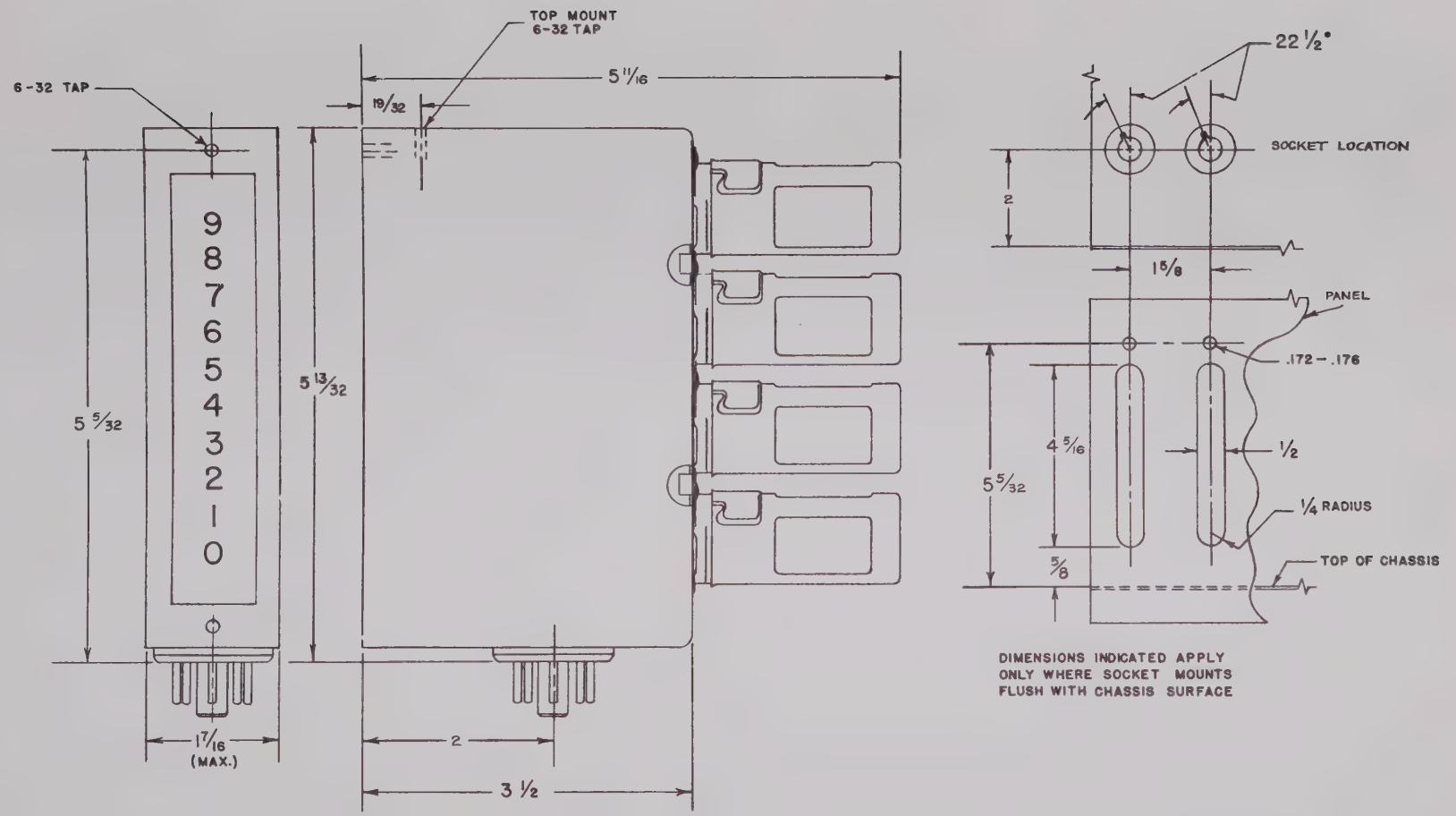


FIG. III-6 MOUNTING DETAILS

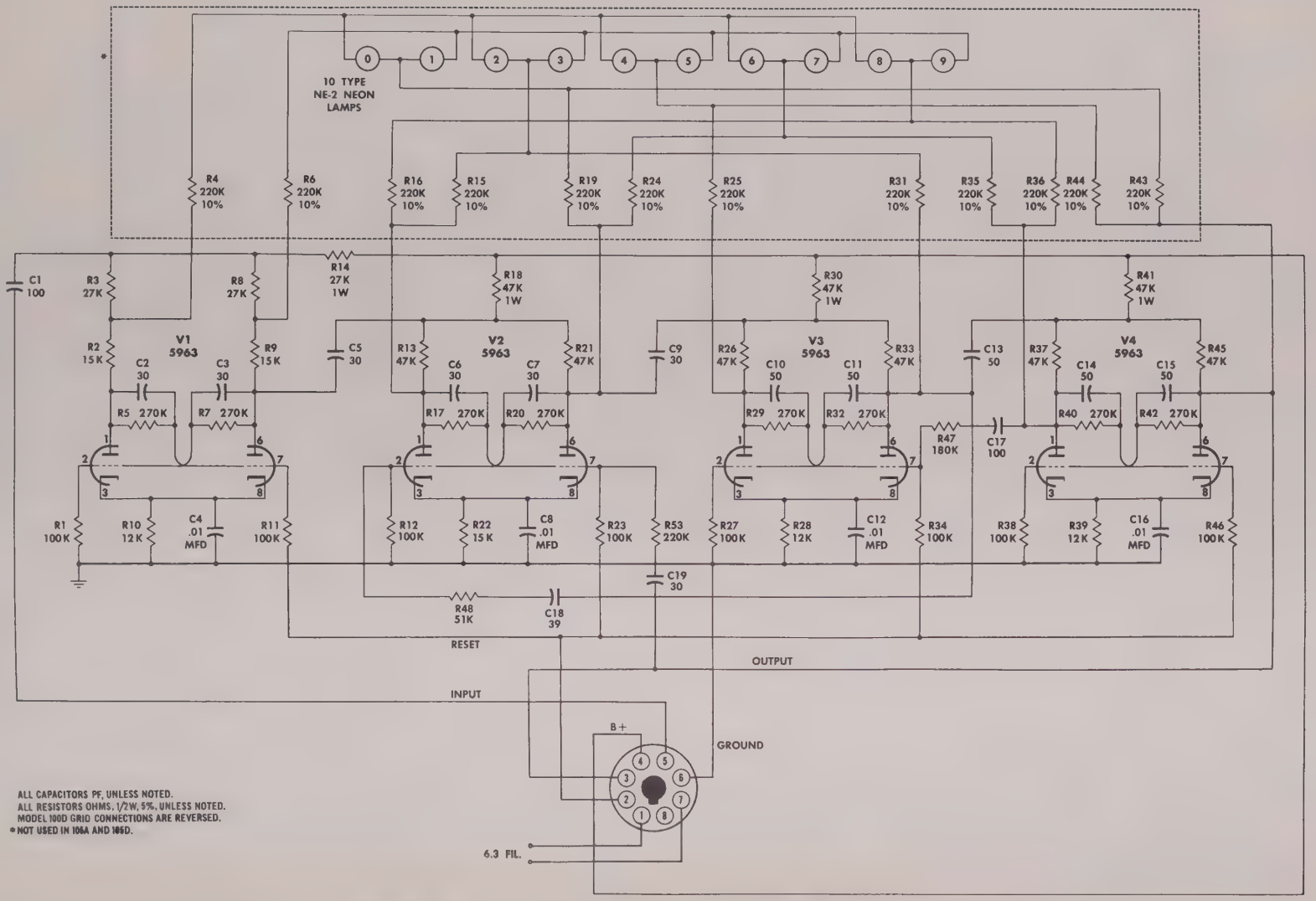
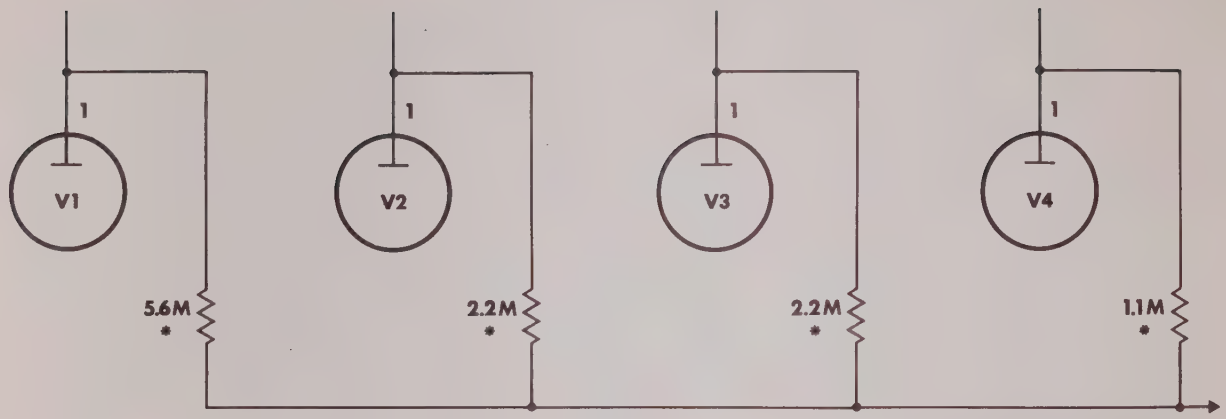


FIG. III-7 MODEL 100A, 100D, 105A & 105D DECADE COUNTING UNIT



* 1/2W 5%

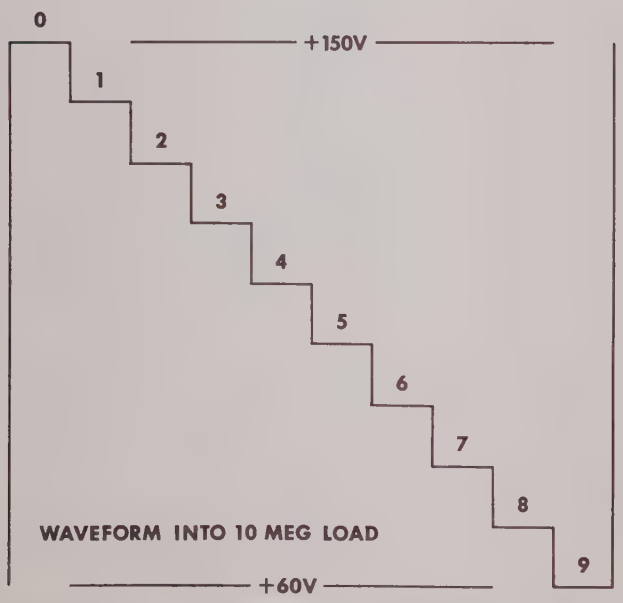
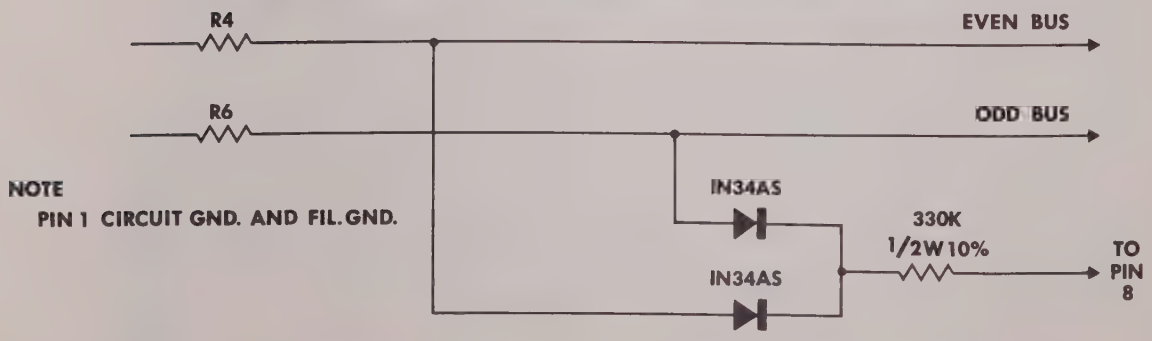
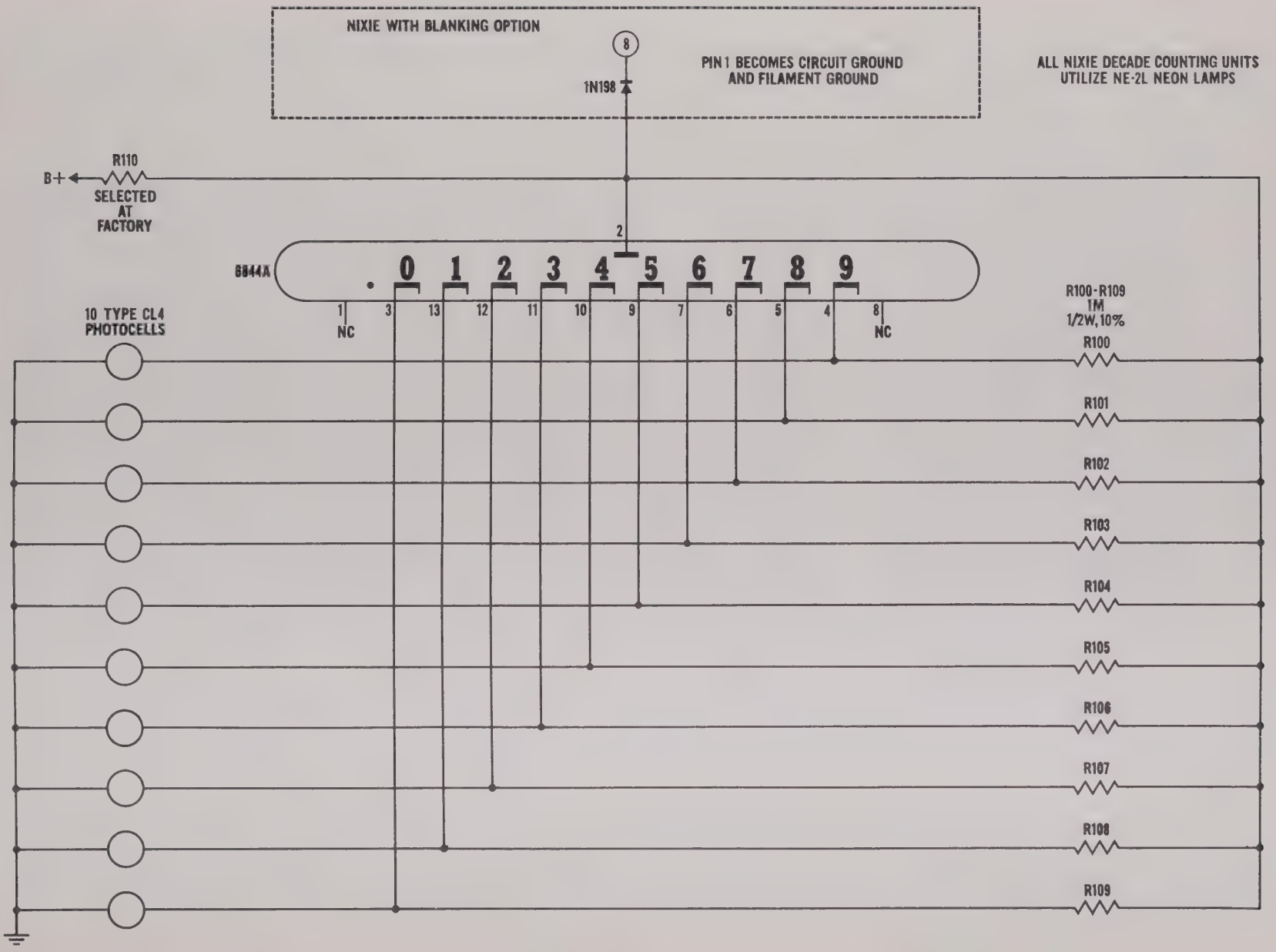


FIG. III-8A MODEL B STAIRCASE OUTPUT



100-178

FIG. III-8B MODEL CB BLANKING OUTPUT


NIXIE WITH BLANKING OPTION
8
1N198
PIN 1 BECOMES CIRCUIT GROUND AND FILAMENT GROUND
ALL NIXIE DECADE COUNTING UNITS UTILIZE NE-2L NEON LAMPS
B+
R110
SELECTED AT FACTORY
2
8844A
0 1 2 3 4 5 6 7 8 9
1 NC 3 13 12 11 10 9 7 6 5 4 8 NC
10 TYPE CL4 PHOTOCELLS
R100-R109 1M 1/2W, 10%
R100
R101
R102
R103
R104
R105
R106
R107
R108
R109

001-58

Symbol No.	Description	CMC Part No.	Mfg. Part No.	Mfg. Code
C1	CAPACITOR, fixed mica 100 mmfd 5% 500WV	C52-101	DM-15E-101J	GG
C2 & C3	CAPACITOR, fixed mica 30 mmfd 5% 500WV	C52-300	DM-15E-300J	GG
C4	CAPACITOR, fixed disc .01 mfd GMV 500WV	C1-103	811 HI-K70	NN
C5-C7	CAPACITOR, fixed mica 30 mmfd 5% 500WV	C52-300	DM-15E-300J	GG
C8	CAPACITOR, fixed disc .01 mfd GMV 500WV	C1-103	811 HI-K70	NN
C9	CAPACITOR, fixed mica 30 mmfd 5% 500 WV	C52-300	DM-15E-300J	GG
C10 & C11	CAPACITOR, fixed mica 50 mmfd 5% 500WV	C52-500	DM-15E-500J	GG
C12	CAPACITOR, fixed disc .01 mfd GMV 500WV	C1-103	811 HI-K70	NN
C13-C15	CAPACITOR, fixed mica 50 mmfd 5% 500WV	C52-500	DM-15E-500J	GG
C16	CAPACITOR, fixed disc .01 mfd GMV 500WV	C1-103	811 HI K70	NN
C17	CAPACITOR, fixed mica 100 mmfd 5% 500WV	C52-101	DM-15E-101J	GG
C18	CAPACITOR, fixed mica 39 mmfd 5% 500WV	C52-390	DM-15E-390J	GG
C19	CAPACITOR, fixed mica 30 mmfd 5% 500WV	C52-300	DM-15E-300J	GG
I1-I10	LAMP, neon	T2-04	NE-2A	00
R1	RESISTOR, fixed composition 100K 1/2w 5%	R9-104	EB1045	D
R2	RESISTOR, fixed composition 15K 1/2w 5%	R9-153	EB1535	D
R3	RESISTOR, fixed composition 27K 1/2w 5%	R9-273	EB2735	D
R4	RESISTOR, fixed composition 220K 1/2w 10%	R10-224	EB2241	D
R5	RESISTOR, fixed composition 270K 1/2w 5%	R9-274	EB2745	D
R6	RESISTOR, fixed composition 220K 1/2w 10%	R10-224	EB2241	D
R7	RESISTOR, fixed composition 270K 1/2w 5%	R9-274	EB2745	D
R8	RESISTOR, fixed composition 27K 1/2w 5%	R9-273	EB2735	D
R9	RESISTOR, fixed composition 15K 1/2w 5%	R9-153	EB1535	D
R10	RESISTOR, fixed composition 12K 1/2w 5%	R9-123	EB1235	D
R11 & R12	RESISTOR, fixed composition 100K 1/2w 5%	R9-104	EB1045	D
R13	RESISTOR, fixed composition 47K 1/2w 5%	R9-473	EB4735	D
R14	RESISTOR, fixed composition 27K 1w 5%	R13-273	GB2735	D
R15 & R16	RESISTOR, fixed composition 220K 1/2w 10%	R10-224	EB2241	D
R17	RESISTOR, fixed composition 270K 1/2w 5%	R9-274	EB2745	D
R18	RESISTOR, fixed composition 47K 1w 5%	R13-473	GB4735	D
R19	RESISTOR, fixed composition 220K 1/2w 10%	R10-224	EB2241	D
R20	RESISTOR, fixed composition 270K 1/2w 5%	R9-274	EB2745	D
R21	RESISTOR, fixed composition 47K 1/2w 5%	R9-473	EB4735	D
R22	RESISTOR, fixed composition 15K 1/2w 5%	R9-153	EB1535	D
R23	RESISTOR, fixed composition 100K 1/2w 5%	R9-104	EB1045	D
R24 & R25	RESISTOR, fixed composition 220K 1/2w 5%	R9-224	EB2241	D
R26	RESISTOR, fixed composition 47K 1/2w 5%	R9-473	EB4735	D
R27	RESISTOR, fixed composition 100K 1/2w 5%	R9-104	EB1045	D
R28	RESISTOR, fixed composition 12K 1/2w 5%	R9-123	EB1235	D
R29	RESISTOR, fixed composition 270K 1/2w 5%	R9-274	EB2745	D
R30	RESISTOR, fixed composition 47K 1w 5%	R13-473	GB4735	D
R31	RESISTOR, fixed composition 220K 1/2w 10%	R10-224	EB2241	D
R32	RESISTOR, fixed composition 270K 1/2w 5%	R9-274	EB2745	D
R33	RESISTOR, fixed composition 47K 1/2w 5%	R9-473	EB4735	D
R34	RESISTOR, fixed composition 100K 1/2w 5%	R9-104	EB1045	D
R35 & R36	RESISTOR, fixed composition 220K 1/2w 10%	R10-224	EB2241	D
R37	RESISTOR, fixed composition 47K 1/2w 5%	R9-473	EB4735	D
R38	RESISTOR, fixed composition 100K 1/2w 5%	R9-104	EB1045	D
R39	RESISTOR, fixed composition 12K 1/2w 5%	R9-123	EB1235	D

Symbol No.	Description	CMC Part No.	Mfg. Part No.	Mfg. Code
R40	RESISTOR, fixed composition 270K 1/2w 5%	R9-274	EB2745	D
R41	RESISTOR, fixed composition 47K 1w 5%	R13-473	GB4735	D
R42	RESISTOR, fixed composition 270K 1/2w 5%	R9-274	EB2745	D
R43 & R44	RESISTOR, fixed composition 220K 1/2w 10%	R10-224	EB2241	D
R45	RESISTOR, fixed composition 47K 1/2w 5%	R9-473	EB4735	D
R46	RESISTOR, fixed composition 100K 1/2w 5%	R9-104	EB1045	D
R47	RESISTOR, fixed composition 180K 1/2w 5%	R9-184	EB1845	D
R48	RESISTOR, fixed composition 150K 1/2w 5%	R9-154	EB1545	D
R49-R52	RESISTOR, fixed composition 1 meg 1/2w 5%	R9-105	EB1065	D
R53	RESISTOR, fixed composition 220K 1/2w 5%	R9-224	EB2245	D
V1-V4	TUBE, electron 5963	T1-11	5963	

MODEL 120C PARTS LIST

Symbol No.	Description	CMC Part No.	Mfg. Part No.	Mfg. Code
C1	CAPACITOR, fixed mica 100 mmfd 5% 500WV	C52-101	DM-15E-101J	GG
C2 & C3	CAPACITOR, fixed mica 30 mmfd 5% 500WV	C52-300	DM-15E-300J	GG
C4	CAPACITOR, fixed mica .01 mfd GMV 500WV	C1-103	811 HI-K70	NN
C5	CAPACITOR, fixed mica 30 mmfd 5% 500WV	C52-300	DM-15E-300J	GG
C6 & C7	CAPACITOR, fixed mica 20 mmfd 5% 500WV	C52-200	DM-15E-200J	GG
C8	CAPACITOR, fixed disc .01 mfd GMV 500WV	C1-103	811 HI-K70	NN
C9	CAPACITOR, fixed mica 20 mmfd 5% 500WV	C52-200	DM-15E-200J	GG
C10 & C11	CAPACITOR, fixed mica 30 mmfd 5% 500WV	C52-300	DM-15E-300J	GG
C12	CAPACITOR, fixed disc .01 mfd GMV 500WV	C1-103	811 HI-K70	NN
C13	CAPACITOR, fixed mica 50 mmfd 5% 500WV	C52-500	DM-15E-500J	GG
C14 & C15	CAPACITOR, fixed mica 30 mmfd 5% 500WV	C52-300	DM-15E-300J	GG
C16	CAPACITOR, fixed disc .01 mfd GMV 500WV	C1-103	811 HI-K70	NN
C17	CAPACITOR, fixed mica 39 mmfd 5% 500WV	C52-390	DM-15E-390J	GG
C18	CAPACITOR, fixed mica 25 mmfd 5% 500WV	C52-250	DM-15E-250J	GG
I1-I10	LAMP, neon	T2-04	NE-2A	OO
R1	RESISTOR, fixed composition 75K 1/2w 5%	R9-753	EB7535	D
R2	RESISTOR, fixed composition 10K 1/2w 5%	R9-103	EB1035	D
R3	RESISTOR, fixed composition 18K 1/2w 5%	R9-183	EB1835	D
R4	RESISTOR, fixed composition 220K 1/2w 5%	R9-224	EB2245	D
R5	RESISTOR, fixed composition 240K 1/2w 5%	R9-244	EB2445	D
R6	RESISTOR, fixed composition 220K 1/2w 5%	R9-224	EB2245	D
R7	RESISTOR, fixed composition 240K 1/2w 5%	R9-244	EB2445	D
R8	RESISTOR, fixed composition 18K 1/2w 5%	R9-183	EB1835	D
R9	RESISTOR, fixed composition 10K 1/2w 5%	R9-103	EB1035	D
R10	RESISTOR, fixed composition 8200 1/2w 5%	R9-822	EB8225	D
R11	RESISTOR, fixed composition 75K 1/2w 5%	R9-753	EB7535	D
R12	RESISTOR, fixed composition 62K 1/2w 5%	R9-623	EB6235	D
R13	RESISTOR, fixed composition 27K 1/2w 5%	R9-273	EB2735	D
R14	RESISTOR, fixed composition 22K 1w 5%	R13-223	GB2235	D
R15 & R16	RESISTOR, fixed composition 220K 1/2w 5%	R9-224	EB2240	D
R17	RESISTOR, fixed composition 200K 1/2w 5%	R9-204	EB2045	D
R18	RESISTOR, fixed composition 36K 1w 5%	R13-363	GB3635	D
R19	RESISTOR, fixed composition 220K 1/2w 5%	R9-224	EB2245	D
R20	RESISTOR, fixed composition 200K 1/2w 5%	R9-204	EB2045	D
R21	RESISTOR, fixed composition 27K 1/2w 5%	R9-273	EB2735	D
R22	RESISTOR, fixed composition 8200 1/2w 5%	R9-822	EB8225	D
R23	RESISTOR, fixed composition 68K 1/2w 5%	R9-683	EB6835	D
R24 & R25	RESISTOR, fixed composition 220K 1/2w 5%	R9-224	EB2245	D
R26	RESISTOR, fixed composition 27K 1/2w 5%	R9-273	EB2735	D
R27	RESISTOR, fixed composition 62K 1/2w 5%	R9-623	EB6235	D
R28	RESISTOR, fixed composition 8200 1/2w 5%	R9-822	EB8225	D
R29	RESISTOR, fixed composition 200K 1/2w 5%	R9-204	EB2045	D
R30	RESISTOR, fixed composition 36K 1w 5%	R13-363	GB3635	D
R31	RESISTOR, fixed composition 220K 1/2w 5%	R9-224	EB2245	D
R32	RESISTOR, fixed composition 200K 1/2w 5%	R9-204	EB2045	D
R33	RESISTOR, fixed composition 27K 1/2w 5%	R9-273	EB2735	D
R34	RESISTOR, fixed composition 62K 1/2w 5%	R9-623	EB6235	D

Symbol No.	Description	CMC Part No.	Mfg. Part No.	Mfg. Code
R35 & R36	RESISTOR, fixed composition 220K 1/2w 5%	R9-224	EB2245	D
R37	RESISTOR, fixed composition 39K 1/2w 5%	R9-393	EB3935	D
R38	RESISTOR, fixed composition 82K 1/2w 5%	R9-823	EB8235	D
R39	RESISTOR, fixed composition 10K 1/2w 5%	R9-103	EB1035	D
R40	RESISTOR, fixed composition 220K 1/2w 5%	R9-224	EB2245	D
R41	RESISTOR, fixed composition 39K 1w 5%	R13-393	GB3935	D
R42-R44	RESISTOR, fixed composition 220K 1/2w 5%	R9-224	EB2245	D
R45	RESISTOR, fixed composition 39K 1/2w 5%	R9-393	EB3935	D
R46	RESISTOR, fixed composition 82K 1/2w 5%	R9-823	EB8235	D
R47	RESISTOR, fixed composition 68K 1/2w 5%	R9-683	EB6835	D
R48	RESISTOR, fixed composition 82K 1/2w 5%	R9-823	EB8235	D
R49-R51	RESISTOR, fixed composition 1 meg 1/2w 5%	R9-105	EB1055	D
V1-V4	TUBE, electron 5963	T1-11	5963	

LEGEND OF CODE LETTERS IN PARTS LIST TO DESIGNATE MANUFACTURERS

Mfg. Code No.	Manufacturer	Address
A	Accurate Sales	Culver City, Calif.
B	Advance Electric & Relay Co.	Burbank, Calif.
C	Aerovox	New Bedford, Mass.
D	Allen-Bradley	Milwaukee 4, Wisc.
E	Elgin-American Microphone	Elgin, Ill.
F	American Pamcor	Hawthorne, Calif.
G	Amperex Electronic Corp.	Hicksville, New York
H	Amphenol Electronics Corp.	Chicago 50, Ill.
I	Ark-Les Switch	Watertown 72, Mass.
J	B & B Magnetics	La Habra, Calif.
K	Barber-Colman Company	Rockford, Ill.
L	Bliley Electric Company	Erie, Pa.
M	William Brand & Company, Inc.	Willimantic, Conn.
N	Bray Optical Company	Los Angeles, Calif.
O	California Chassis	South Gate, Calif.
P	California Spring Company, Inc.	Rivera, Calif.
Q	Camloc Fastener Corp.	Paramus, New Jersey
R	Cannon Electric Company	Los Angeles, California
S	C. F. Cannon Company	Springwater, New York
T	Carling Electric Inc.	W. Hartford 10, Conn.
U	Centralab	Milwaukee 1, Wisc.
V	Chicago Telephone of California	Pasadena, Calif.
W	Clarostat Mfg. Company, Inc.	Dover, New Hampshire
X	Conant Laboratories	Lincoln, Nebraska
Y	Cornell Dubilier Electric Company	S. Plainfield, New Jersey
Z	Dale Products, Inc.	Columbus, Nebraska
AA	Davies Moulding Company	Chicago 10, Illinois
BB	Dial Light Company of America	Brooklyn 37, New York
CC	Dot Fastener Company	Cambridge, Mass.
DD	Dzus Fastener Company, Inc.	Babylon, New York
EE	Eclipse Engineering	Los Angeles, California
FF	Elco Corp.	Philadelphia, Pa.
GG	Electro Motive Mfg. Company, Inc.	Willimantic, Conn.
HH	Cinch-Jones Mfg. Company	Chicago, Illinois
II	Veeder-Root, Inc.	Hartford 2, Conn.
JJ	Belden Mfg. Co.	Chicago, Ill.
KK	Hugh H. Eby Company	Philadelphia, Pa.
LL	Corning Glass Works	Corning, New York
MM	Empire Spring Company	Elyria, Ohio
NN	Erie Resistor Corp.	Erie 6, Pa.
OO	General Electric Company	Schenectady, New York
PP	General Electric Co., Supply Corp.	Los Angeles, Calif.
QQ	General Radio Company	Cambridge 39, Mass.
RR	Goe Engineering Company	Los Angeles, Calif.
SS	Greyhill	La Grange, Ill.
TT	Girard-Hopkins	Oakland, California
UU	Grigolett Company	Decatur, Ill.
VV	Robert M. Hadley Company	Los Angeles, California
WW	Harshaw Chemical Company	Cleveland, Ohio
XX	Hopkins Engineering	San Fernando, California
YY	Insuline Corp. of America	Manchester, N. H.
ZZ	International Rectifier Corp.	El Segundo, California
AB	International Resistance Company	Philadelphia, Pa.
AC	Kemtron	Newburyport, Mass.
AD	Lenz Electrical Co.	Chicago, Ill.
AE	Landsverk Electrometer Company	Glendale, California
AF	P. R. Mallory Co., Inc.	Indianapolis, Ind.
AG	J. A. Meyer & Company	Los Angeles, California
AH	Micro Switch	Freeport, Ill.
AI	J. W. Miller Company	Los Angeles, California
AJ	Miller Gasket Company	Huntington Park, California
AK	National Carbon Company	San Francisco, California
AL	National Company	Malden, Mass.
AM	Oak Mfg. Company	Chicago, Ill.
AN	Pacific States Supply	Los Angeles, California
AO	Pax Metal Company	Van Nuys, California
AP	Phelps Mfg. Company	Westport, Conn.
AQ	Potter Brumfield, Inc.	Princeton, Indiana
AR	Globe Electrical Mfg. Co.	Gardena, Calif.
AS	Presin Company	Los Angeles, Calif.
AT	Prestole Corp.	Toledo, Ohio
AU	Pulse Engineering	Redwood City, Calif.
AV	Radio Corp. of America	Harrison, New Jersey
AW	Radio Receptor Corp.	New York, New York
AX	Raytheon Mfg. Company	Newton, Mass.
AY	Sangamo Electric Company	Marion, Ill.
AZ	Simpson Electric Co.	Chicago, Ill.
BC	Sprague Electric	North Adams, Mass.
BD	Stackpole Carbon Company	St. Marys, Pa.
BE	A. C. Swanson Company	Sun Valley, Calif.
BF	Switch Craft Inc.	Chicago, Ill.
BG	Sylvania Electric Products Company	Warren, Pa.
BH	Synthane Corp.	Oaks, Pa.
BI	Triad Transformer	Venice, Calif.
BJ	Trimm, Inc.	Libertyville, Ill.
BK	Triplett Electrical Inst. Co.	Bluffton, Ohio
BL	Tung Sol Lamp Works Inc.	Newark, New Jersey
BM	Union Switch	Swissvale, Pa.
BN	U.S. Radium Corp.	N. Hollywood, Calif.
BO	Vector Electronic Company	Los Angeles, California
BP	Cutler Hammer	Milwaukee, Wisc.
BQ	Waugh Engineering	Van Nuys, Calif.
BR	Microdot	S. Pasadena, Calif.
BS	Wilco	Indianapolis, Ind.
BT	Mueller Electric Company	Cleveland, Ohio
BU	James Knight Company	Sandwich, Ill.
BV	Torrington Mfg. Company	Van Nuys, Calif.
BW	Ohmite Mfg. Company	Skokie, Ill.
BX	Arco Electronics	New York, New York
BY	Arrow Hart & Hageman	Hartford, Conn.
BZ	Littlefuse	Des Plaines, Ill.
CD	Heyman Mfg. Company	Kenilworth, New Jersey
CE	Waldes Kohinoor, Inc.	Long Island City, N. Y.
CF	Vanguard Electric	Los Angeles, Calif.
CG	Commercial Plastics	Chicago, Ill.
CH	Viking Electric	Canoga Park, Calif.
CI	Winchester Electronics, Inc.	Norwalk, Conn.
CJ	Parker Appliance Company	Cleveland, Ohio
CK	Burton-Rogers Company	Cambridge, Mass.
CL	Sarkes-Tarzian, Inc.	Bloomington, Indiana
CMC	Computer Measurements Corp.	N. Hollywood, Calif.
CN	Johnson Adding Machine Company	N. Hollywood, Calif.
CO	Clary Corporation	San Gabriel, California
CP	Turbo-Jet Products Company	San Gabriel, California
CQ	Minarik Electric	Los Angeles, California
CR	NYT Electronics	Burbank, California
CS	Modern Screw Machine Company	Burbank, California
CT	Christian & Company	North Hollywood, Calif.
CU	North & Judd Mfg. Company	San Gabriel, California
CV	Rho Engineering	Los Angeles, California
CW	Richey Air Sales	North Hollywood, Calif.
CX	General Cement Company	Rockford, Illinois
CY	Airad Sheet Metal Company	Van Nuys, California
CZ	Amperite Company, Inc.	New York, New York
DE	Autron Engineering	Los Angeles, California
DF	Calif. Pantograph Engravers	Burbank, California
DG	Clairex Corporation	New York, New York
DH	Component Mfg. Service	W. Bridgewater, Mass.
DI	Davis Electric Company	Cape Girardeau, Mo.
DJ	Empcor Company	Burbank, California
DK	Electro Products Lab.	Chicago, Illinois
DL	Ess Instrument Company	Bergenfield, New Jersey
DM	Globe Electric Company	Los Angeles, California
DN	Hufco Industries	Burbank, California
DO	Kemtron Electron Products	Newburyport, Mass.
DP	Mepco, Inc.	Morristown, New Jersey

WARRANTY

Electron Tube Instruments

All electron tube instruments manufactured by Computer Measurements Company are warranted to be free from defects in material and workmanship subject to the following conditions and exceptions:

A. CMC agrees to correct, either by repair or at CMC's election, by replacement, any defects which arise within a one-year period from the original date of delivery, provided that investigation and inspection by CMC discloses that such defects developed under normal and proper use.

B. Warranty is extended only to those instruments which have been returned transportation prepaid in compliance with our shipping instructions.

C. Warranty is void for instruments which have been subjected to abuse or improper conditions or in the event repairs or modifications are made by persons other than CMC's own service personnel or authorized representatives, unless such repairs are made with the written consent of CMC.

D. CMC makes no warranty concerning components not manufactured by CMC, such as electron tubes, which carry the warranty of the original manufacturers.

E. For damage resulting from shipment, prompt claims should be filed with the transportation company concerned and request made that the information be forwarded to CMC.

For faults not covered in this warranty, first report to CMC all details of malfunction or inoperation. Pertinent information or shipping instructions will be promptly given. During the warranty period all repairs not covered by this warranty will be billed at cost.

All correspondence concerning the instrument should specify the model and serial numbers. This information appears on the Company name plate. Any inquiry concerning the details of operation, possible modifications, etc., should be addressed to the Sales Department.

Computer Measurements Company, a Division of Pacific Industries, Inc.
San Fernando, California

CMC COUNTERS

CONDENSED CATALOG FOR REFERENCE TO MOST POPULAR MODELS

CMC

LATEST PRICES ARE SHOWN ON THE REVERSE SIDE OF THIS PAGE

COMPUTER MEASUREMENTS COMPANY IS A LEADING DESIGNER AND MANUFACTURER OF ELECTRONIC INSTRUMENTATION TO COUNT, MEASURE, AND CONTROL.

CMC

CMC PRICE LIST

403A	1050.00
404A	780.00
410A	1480.00
600A	865.00
601A	965.00
602A	1050.00
603A	1175.00
604A	1300.00
605A	1425.00
607A	1725.00
614A	1425.00
616A	2185.00
633A	325.00
634D	825.00
702A	1325.00
706C	1625.00
707D	2200.00
726C	1825.00
727C	2375.00
727D	2475.00
738A	1925.00
738B	1750.00
784C	965.00
786C	1175.00
800A	2260.00
801A	440.00
802A	640.00
803A	1425.00
810A	1800.00
831A	35.00
831B	95.00
832A	175.00
832B	235.00
833A	290.00
833B	350.00
834B	540.00
834D	825.00
835A	835.00
838A	750.00
846A	1550.00
880A	3550.00
884A	750.00
885A	825.00
886A	1550.00

CMC COUNTERS

JUST A FEW EXAMPLES OF CMC INSTRUMENTS TO COUNT, MEASURE AND CONTROL.

600 SERIES ALL SILICON SOLID-STATE 2.5, 5, AND 225 MC COUNTERS

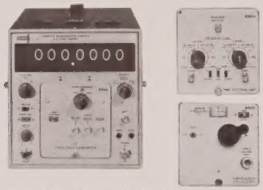
CMC's 600 series are the first counters built with all silicon semiconductors for higher reliability, superior temperature stability. Maximum frequency ranges of 2.5, 5 and 225 mc. Simplified design techniques and advanced "Mother Board" circuitry reduce components by 10 per cent over competitive models. Temperature operation −20 to +65° C standard, −30 to +75° C available. All silicon memory (display storage), a standard feature, is not subject to slow response and upper temperature limitations of photoconductor memory circuits. Automatic decimal point. Panel height is just 3½ inches. 0.1 volt rms sensitivity. Two year free service warranty.

2.5 MC FREQUENCY COUNTER
Measures frequency, determines frequency ratio, and totalizes. Frequency measurement range −2 cps to 2.5 mc. Digital output for printer, tape punch, etc. Four decades standard, up to six decades available for increased registration. All silicon solid-state. **Model 600A** double-column neon lamp display. **Model 601A** inline long-life biquinary display. Both with memory.

2.5 MC FREQUENCY AND PERIOD COUNTER
Measures frequency and period, determines frequency ratio and totalizes. Frequency, frequency period and frequency ratio measurement ranges: 2 cps to 2.5 mc. Period average and multiple ratio: 1, 10 and 100. Weighs only 18½ lbs. All silicon solid-state reliability. **Model 602A:** double-column neon lamp display. **Model 603A:** inline, long-life biquinary display. Five decades are standard, a sixth is optional. Both with memory.

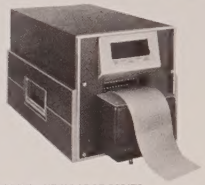
2.5 Mc UNIVERSAL COUNTER-TIMER
Measures frequency, period, time interval with internal or external clock, frequency ratio, and totalizes. Time interval measurement range: 10 μsec to 10^4 sec. Period and frequency ratio measurement ranges: 0 to 2.5 mc. Period average and multiple ratio: 1, 10 and 100. **Model 604A:** double-column neon lamp. **Model 605A:** inline biquinary display. Five decades standard, sixth decade optional. Memory is standard. All silicon solid-state.

5 MC UNIVERSAL COUNTER-TIMER
Measures frequency, period, multiple period average, frequency ratio, time interval, and totalizes. Frequency measurement range: 0 to 5 mc. Period: 0 to 1 mc. Multiple period average measurement to 10^7 from 0 to 2.5 mc. 1 mc crystal time base; stability ±2 parts in 10^7 per month. Six decade inline biquinary display; automatically positioned decimal point; memory. All silicon solid-state. **Model 607A.**



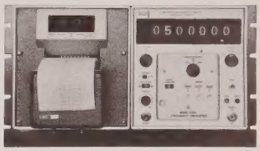
NEW 225 MC FREQUENCY METER
Model 616A provides low cost direct frequency measurement from 10 cps to 225 mc by means of a unique prescaler built into the instrument. Simple plug-ins extend frequency to 1000 mc, 3000 mc or 12 gc. Plug-in for time interval measurement from 1 μsec to 10 sec with resolution of 1 μsec (.1 μsec optional) also available. This ruggedly built, easily operated half rack size instrument is ideal for general laboratory use or field applications. It can be rack mounted side by side with the CMC 410A Digital Printer. All silicon semiconductor circuitry assures dependable operation over wide temperature ranges. 1 mc crystal time base; stability ±2 parts in 10^7 per month. Seven decade inline display is standard — eighth decade optional. Front panel switch permits selection of (1) direct frequency measurement, 10 cps to 10 mc, (2) prescaled frequency measurement, 500 kc to 225 mc, or (3) extended frequency measurement with plug-in frequency converter. All frequencies displayed in kilocycles. Standard automatic decimal and memory. **Model 633A** Time Interval Meter plug-in for **Model 616A** has range of 1 μsec to 10 sec with resolution of 1 μsec (.1 μsec optional). **Model 634D** Frequency Converter plug-in for **Model 616A** provides additional measurement capability up to 3000 mc.

NEW 10-Line/Sec. DIGITAL PRINTER

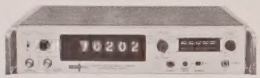


HIGH-SPEED, NEW LARGE DIGITS, SOLID-STATE DRIVE AND LOGIC
Fastest, easiest to read, not a modified adding machine or calculator. 35 millisecond data acquisition. Prints 12 columns at 10 lines per second. Electrically positioned decimal without loss of digit. Left zero elimination. New simple electromagnetic design eliminates commutators and moving contacts. Column suppression on command. Fan-fold or roll paper. Half rack size. Up-front pushbutton controls. Error-identifying seven-segment printed character. Eight columns are standard. More or less are optionally available. **Model 410A.**

RACK MATES: 616 WITH 410



IT'S THE IDEAL MARRIAGE
Mount the 616A Frequency Meter with the 410A Digital Printer. Each being half rack size and rugged all silicon design, these two perfect rack mates fit just about anywhere you want to put them. Together they are an unbeatable combination for measuring and recording. See descriptions of 616A (at left) and 410A (above). Special mounting rack is available.



NEW 2.5 MC ALL SILICON PRESET COUNTER
Model 614A Preset Multi-function Counter, extends applications to normalizing and multiplication by any preselected constant. Gate time presets to any interval from 10 μsec to 100 seconds. Gate time presets by remote selection. Direct display as mph, rpm, ms per N periods, etc. 614A also measures frequency and period and totalizes. Frequency range; 2 cps to 2.5 mc. Period and frequency ratio ranges; 2 cps to 500 kc. Preset count circuitry operates dependably at frequencies through 300 kc — up to three times as fast as other variable gate time counters. 100 kc crystal time base; stability ±2 parts in 10^8 per week. Standard five decade inline biquinary display (sixth optional), with automatically positioned decimal point and memory.

CMC COUNTERS

CRUSADING ENGINEERS: WRITE FOR LITERATURE AND "CHECK THE SPECS."

MILITARIZED SOLID-STATE 100 MC COUNTER

FULLY MILITARIZED 100 MC COUNTER

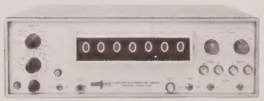
Model 880A is the first and only solid-state counter fully militarized to meet Mil Specs. It measures frequency, period, multiple period average, frequency ratio, frequency ratio average, time interval with internal and external clock, and totalizes; scales input frequency in decade steps; provides standard frequency outputs. If you want the safety of a counter providing full Mil Specs reliability at a price surprisingly close to a commercial counter, then check these specs: 0 to 100 mc frequency range; oscillator stability of 1 part in 10^9; meets or exceeds MIL-E-16400, including appropriate temperature, humidity, vibration, shock, and RFI specs; built-in time interval measurement. Eight decade inline display. Militarized plug-ins available (see below).

PLUG-INS FOR MILITARIZED 880A

Model 884A, Frequency Converter plug-in extends Model 880A range to 500 mc. Solid-state circuitry. Acceptance-tested to MIL-E-16400, MIL-S-901, and MIL-I-16910. Step selector switch. **Model 885A,** Heterodyne Frequency Converter with range from 100 mc to 3200 mc. **Model 886A,** Transfer Oscillator plug-in with frequency range from 0.1 gc to 1.0 gc (on band 1) and 1.0 gc to 12 gc (on band 2).

50 MC, 25 MC, 13 MC FREQUENCY-PERIOD COUNTERS

Model 707D directly measures frequency from 0 cps to 50 mc, single period 0.3 μsec to 10^8 sec and multiple period 1 to 10^7. Accuracy: ±1 count ± oscillator accuracy: Oscillator stability: ±3 parts in 10^7 per month standard, ±3 parts in 10^9 per day optional. Resolution 0.1 μsec. Low power consumption: 75 watts. Seven decade inline readout. Eighth decade optional. Display storage is standard. **Model 707C,** 0 cps to 25 mc Frequency Period Counter, provides all other specs listed for **Model 707D** above. **Model 706C** measures frequencies of 0-13 mc, provides all other specs of 707D, except that memory is optional.

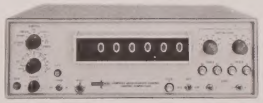


50 MC, 25 MC, 13 MC UNIVERSAL COUNTER-TIMERS

Model 727D directly measures frequency from 0 cps to 50 mc and single period and time interval from 0.3 μsec to 10^8 sec, multiple period of 1 to 10^7. Oscillator stability ±3 parts in 10^7 per month standard, ±3 parts in 10^9 per day optional.

Accuracy: ±1 count ± oscillator accuracy. Memory is standard. Resolution 0.1 μsec. Seven decade inline readout. Eighth decade optional. All solid-state. Operates on only 75 watts.

Model 727C, 0 cps to 25 mc Universal Counter-Timer, provides all other specs listed for **Model 727D** above.



LOW COST 13 MC UNIVERSAL COUNTER-TIMER

Six decade inline NIXIE readout. **Model 726C** measures frequencies of 0 to 13 mc. This low cost unit provides all the basic specs listed for Model 727D (shown above) except that display storage is available as an option. Multiple period (1 to 10^7). Single period and time interval range of 0.3 μsec to 10^7 sec. Oven controlled crystal stability of ±5 parts in 10^8.

SOLID-STATE GO, NO-GO COMPARATOR

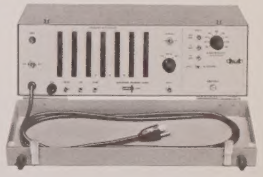
Model 404A compares a binary coded decimal number, obtained from printer output receptacle of a counter with two selected preset numbers in the comparator for go, no-go operation. Provides visual display in "HI", "LO", and "IN" limit lights as well as contact closure outputs for control purposes. Half rack size permits dual mounting. Weighs only 17 lbs. and uses just 45 watts power. Four decade preset standard, up to 8 optional. Remote presetting of limits optional.

SOLID-STATE DUAL PRESET COUNTER-CONTROLLER

Ideal for critical applications where instrument down-time cannot be tolerated. Absolute accuracy, 100 mv sensitivity, high recycling rate (100 kc), low power consumption (25 watts). **Model 786C** has six decades and count capacity of 1 to 999,999. "Count" and "Reset" contact closures at rear panel for remote operation. **Model 784C** has four decades and count capacity of 1 to 9,999.

100 MC DIRECT READING FREQUENCY METER

Directly measures frequency from 10 cps to 100 mc. Extends to 500 mc in 50 mc steps with optional positive switching turret-type heterodyne converter, which requires no tuning. All solid-state. Accuracy ±1 count ± oscillator accuracy. Oscillator stability ±3 parts in 10^7 per month. Lightweight—35 lbs. Low power consumption—60 watts. **Model 738A** (shown with converter), seven decade NIXIE® readout, for bench use.



Model 738B is the rugged, portable field instrument version of Model 738A (above) with a metal cover to protect the front panel. It has a seven decade vertical readout. Now available with **Model 735C** heterodyne converter.

CMC Rutherford

EARN YOUR CMC CRUSADING ENGINEERS MEDAL

ANNOUNCEMENT: RUTHERFORD ELECTRONICS BECOMES CMC DIVISION

CMC has acquired the assets of Rutherford Electronics Co., the nation's best-known producer of pulse generators. Rutherford will function as a division of CMC.

CMC President John K. Rondou termed the acquisition "the first major step in CMC's long-range expansion program, which includes the goal of providing a wide variety of test instruments for scientific and engineering research."

He noted that the expansion program "already is underway. We've more than doubled our number of employees during the past year and are planning to expand our San Fernando facilities, in addition to the acquisition of the Rutherford plant."

CMC's sales during the first half of 1965, Rondou added, were up 60 per cent over the same period of 1964.

Rutherford, headquartered in El Segundo, Calif., was founded 15 years ago by Charles E. Rutherford, one of the pioneers of the pulse generator field. The company's 1964 sales were approximately $1,000,000.

Present management and personnel of Rutherford will remain with the company, Rondou stated.

CMC, which has an intensive applied R&D program, plans "some immediate product improvement for its newest line," Rondou said, "including application of digital techniques to pulse generating operations."

BASIC PULSE GENERATOR

Well known as "The Standard of the Industry" the general purpose B-7B features rep rates to 2 mc and outputs of 50 volts into 50 ohms. Printed circuit boards. Variable rise time control. Trouble-free single unit construction. Overload protection. Stabilized noise-free repetition rate schedule.

Model B-7B **$720.00**

DIGITAL DYNAMIC DELAY SIMULATOR

Video target simulator that can evaluate, check, and calibrate today's most sophisticated weapons control and tracking systems. Range to 1 million feet, velocity to 100,000 ft/sec., and acceleration to 10,000 ft/sec/sec. **Model S1** **$6,000.00**

PORTABLE PULSE GENERATOR

The versatile, low cost, pulse generator features rep rates to 2 mc and outputs to 8 volts into 50 ohms. All solid-state. Portable — AC or battery operated. Overload and short circuit protection. Independently variable width, delay, polarity, and amplitude. **Model B-14** **$385.00**

20 MC PULSE GENERATOR

This high speed, solid-state model has a 10 volt output into 50 ohms with rise and fall times less than 10 nanoseconds. Repetition rate: 20 cps to 20 mc. Pulse delay is 0 to 10,000 μsec. Pulse width of 0.015 to 10,000 μsec. Single or pulse pair operation. May be gated for pulse burst. **Model B16** **$875.00**

DIGITAL TIME DELAY GENERATOR

Time delays settable from 0 to 1 second in 100 nanosecond increments. Accuracy 0.001% of delay. Jitter, less than 1 nanosecond. Half-rack width. Solid-state circuitry. **Model A-11** **$975.00**

USE ENCLOSED REPLY CARD

In addition to a full line of counters and Rutherford pulse and time delay generators, CMC offers engineering experience in special-purpose "black boxes," data gathering and logging systems, and industrial automation and process controls. **Write for complete technical literature.**

COUNTERS

WRITE FOR LITERATURE AND "CHECK THE SPECS"

800 SERIES SOLID-STATE DUAL PLUG-IN

25 MC, 50 MC, 110 MC
CMC's Digi-Twin® is the most versatile solid-state counter available. Frequency to 110 mc direct counting. Time measurements to 10 nanosecond resolution. Plug-ins for both frequency range and function. Select plug-ins to best meet your current needs. As your needs change, buy new plug-ins, not new instruments. Ask about our range module trade-in program. Advanced Mother Board design and printed circuit plug-in cards provide outstanding reliability, ease of maintenance. Two year free service warranty. Printer output. Automatic decimal point. The basic chassis contains the power supply, NIXIE® readout, 1 mc crystal oscillator with decade countdown time base and related circuitry.

TWO BASIC CHASSIS CHOICES
The **Model 800** chassis provides 8 decade readout; memory is standard. Gate times: 1 μsec to 100 sec in decade steps. Oscillator stability: ±3 parts in 10^8 per day.

A low-cost **Model 810** basic chassis is available for those who need full Series 800 versatility, but have less exacting measurement requirements. Six decades are standard; memory is optional. Gate time from 1 μsec to 1 second in decade steps. Oscillator stability ±3 parts in 10^7 per week. Choice of performance options to fit needs. Uses standard Series 800 range and function plug-ins.

PLUG-INS FOR 800 SERIES COUNTERS

The CMC 800 Series Digi-Twin is the only solid-state digital electronic counter that offers a choice of both frequency range and function module plug-ins. Described below are three Frequency Range modules, three basic Function modules, and five Special Purpose modules available at this time. By starting with the basic Model 800A chassis, and selecting a frequency range and function module, you can tailor-make a digital counter to meet your present requirements. As your requirements change, simply select individual modules to meet your new application . . . at a fraction of the cost of an entirely new instrument.

THREE FREQUENCY RANGE MODULES
Maximum frequency ranges for plug-ins: **Model 801A** is 25 mc, **Model 802A** is 50 mc. **Model 803A** is 110 mc. Accuracy is the same as for basic counter (see above).

FUNCTIONAL PLUG-IN VERSATILITY
Three basic function modules (illustrated) available, two frequency period and one counter-timer. Period measurement: **831A** and **B** 0.5% accuracy; **832** and **833A** and **B** 0.3% accuracy. Time interval measurement range: 0.1 μsec to 10^{4*} sec with 801A and 802A; .03 μsec to 10^{4*} sec with 803A. "B" Models are remotely programmable.
*10^4 with standard 810 chassis.

Five special purpose modules are currently available: **Model 834B,** 600 mc heterodyne converter offers range measurement from 50 mc to 600 mc in 10 mc steps. **Model 834D,** heterodyne converter with frequency range from 100 mc to 3200 mc. **Model 835A,** Integrating Digital Voltmeter with measurement ranges of 0.1v, 1.0v, 10.0v, 100v, and 1000v full scale. **Model 838A,** digital phase meter with range from 10 cps to 100 kc, and accuracy of 0.5. **Model 846A,** is a 0.1 gc to 12 gc transfer oscillator with built-in self-test (not shown).

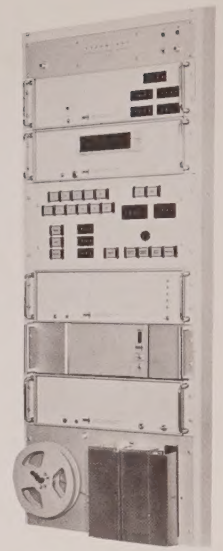
SYSTEMS CAPABILITIES

Model 2774A — Special Purpose Time Interval Meter with printer. For continuous period measurement. Built for Naval Electronics Laboratory.

Model 1144A — Special Purpose Counter. A repackaging of a standard 10 mc counter.

Model 3619 — Remote readout with standard 603A counter for remote display.

Model 2622A—Automation and Process Control System. Coil Winder Controller.



Large System — Data Gathering and Data Logging. Built for Rantec.

SPECIAL PURPOSE "BLACK BOXES" — In addition to its versatile standard product lines, CMC specializes in several areas of custom-engineered applications. Foremost among these is the design of special-purpose black boxes to specific customer requirements. Many of these are built for customer re-sale, frequently under the customer's own name. The following are typical examples:

- Medical Instrumentation
- Gyro Test Sets
- Reversible Counters (Bi-directionals)
- Nuclear Scalers and dual scalers
- Automatic Test Sets
- Oscillator Test Sets
- Communications Counters
- Digital Clocks
- Scanners
- Parallel to serial converters
- Preset Controllers

CMC has on file many standard designs for these applications, which can be converted to specific customer requirements in minimum time and at minimum cost.

DATA GATHERING AND DATA LOGGING SYSTEMS — These systems combine custom-engineered and/or modified standard CMC products to perform specific data handling functions. The following are representative of CMC's capability in this field:

- Nuclear Scaler Systems
- Cosmic Ray Observatory Data Logging System
- Shock-wave Velocity Measuring System
- Discharge Measuring Systems for Rivers and Canals
- Ballistic Data Logging Systems

INDUSTRIAL AUTOMATION AND PROCESS CONTROL SYSTEMS
CMC has also demonstrated outstanding capabilities in the field of custom-engineered Industrial, Production and Control Systems. Typically, these installations provide the user with accurate and reliable quantitative data on either an absolute or a go, no-go basis. Permanent data can be supplied by digital printers, tape perforators, or electric typewriters.

The following is a partial list of CMC-designed systems presently in operation:

- Automatic Weighing System for Railroad Cars
- Component Electrical Checkout Systems with Automatic Accept-Reject Limits
- Automatic Shear Control for Roll and Plate Steel Mills
- Automatic Control System for Multiple Tap Coil Winding Machines
- Automatic Horn Testing System for Auto Industry

FREE TECHNICAL INFORMATION AVAILABLE — The purpose of this short-form catalog is to give you a very brief look at our range of standard instruments. Perhaps one or more specific models interest you. Then, as a Crusading Engineer, you will want to "Check The Specs". The best way is to use the enclosed reply card (or a letter if you have specific questions or problems) to request complete technical data and specifications on any instrument. Your request will be answered promptly.

CMC

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COMPUTER MEASUREMENTS COMPANY IS A LEADING DESIGNER AND MANUFACTURER OF ELECTRONIC INSTRUMENTATION TO COUNT, MEASURE, AND CONTROL